Food Product Surface Sterilization Apparatus and Method

Related Applications

The present application claims the benefit of, and incorporates fully by reference, each the following: U.S. Provisional Patent Application Serial No. 60/393,792 filed July 3, 2002; U.S. Provisional Patent Application Serial No. 60/393,363 filed July 3, 2002; and U.S. Provisional Patent Application Serial No. 60/449,725 filed February 24, 20034.

RELATED FIELD OF THE INVENTION

The present invention relates generally to the field of sterilization equipment, and, more specifically, to a device for surface sterilization of foodstuffs of various regular or irregular shapes, this device includes a combination of germicidal radiation, ozone and a device for rotating and conveying the foodstuffs such as (a) a rotating drum that lifts, tumbles, and advances the foodstuff within the drum in the presence of the germicidal radiation, and (b) a screw conveyor that lifts, tumbles, and advances the foodstuff within the screw conveyor in the presence of the germicidal radiation and/or ozone.. Foodstuffs mentioned here mean edible products and ingredients that should be sterilized because of public health.

Background of the Invention

Various processes have been used to sterilize foodstuffs. Thermal processing of foodstuffs so that they will be safe for consumption is used in a variety of forms. For example, foods are commonly sterilized and preserved by commercial canning processes in which a food product is placed in a hermitically sealed container and then heat processed. For fruit and vegetable products, the canning process alters the flavor and textural qualities of the food product. An alternative to the canning process for vegetables is the blanch frozen process, in which fresh vegetables are thermally processed in the blanching process to inactivate enzymes, then frozen for preservation of the vegetables. In water blanchers, the water is typically chlorinated to provide surface sterilization of the vegetables. Some vegetables, such as French fried potatoes, are blanched and partially fried prior to freezing for preservation. For fresh fruits and

vegetables, the food product (also denoted herein as "foodstuff") is typically washed in chlorinated or other chemically treated water to destroy surface bacteria. In cooked meat products, the food product is cooked to a temperature sufficient to destroy microorganisms, then chilled or frozen for preservation of the cooked meat product. In dry foodstuffs such as nuts and grains, such foodstuffs are bathed in an atmosphere or solution of chemicals that are toxic to microorganisms (e.g., yeast, mold spores, fungi), and the egg and/or larva of insects. However, the chemicals used are costly and may leave a residue, which can be ingested by the consumer. Moreover, such chemical treatments are not always effective in view of the numerous instances of live and dead insects and mold still encountered in packaged dry foodstuff products.

In foodstuffs which are frozen for preservation, such as blanched vegetables, partially fried potato products, and cooked meat products, the thermal or chemical bacteria kill process is prior to the freezing and packaging of the foodstuffs. In the freezing and packaging processes, the probability of surface re-contamination of the foodstuff exists. Processors of these products regularly test the frozen products for microorganisms resulting from surface contamination. Products with contamination are either sent to waste, or reprocessed to again thermally or chemically kill the microorganisms.

It is well known that ultraviolet radiation, particularly ultraviolet radiation having a wavelength of approximately 254 nanometers (nm), and more generally, in the range of 235-280 nm (such radiation denoted herein as "UVC"), kills microorganisms including yeast, mold spores, bacteria, fungi, as well as the eggs and/or larva of insects. In the August, 2000 issue of "Meat & Poultry" magazine, an article by Richard Stier (entitled "Shedding some light. Pulsed Light Sterilization- a Tool for the Future", pages 60 through 63, herein incorporated fully by reference) includes dosage quantities in milliwatt- seconds per square centimeter to achieve 90% kill of common bacteria, mold spores, and viruses. In the February, 1996 issue of "Heating/Piping/Air Conditioning" magazine, an article entitled " Using UVC Technology to Enhance IAQ", (herein incorporated fully by reference) by Robert Scheir, PhD and Forrest B. Fencl define UVC germicidal energy required to achieve 90% kill of common microorganisms for bacteria, yeasts, and mold spores.

Many mechanisms have been devised which use ultraviolet radiation for the protection of foods, pharmaceuticals, and other products affected by microorganisms and/or insect eggs/larvae. Some references disclosing foodstuff sterilization techniques that have been attempted are as follows (these references being fully incorporated herein by reference):

(a) U.S. Patent No. 6,132,784 filed February 19, 1999 by Brant et. al. (incorporated fully by reference herein) describes a method and apparatus in which round fresh fruits and vegetables are conveyed on a conveyor with rotating rollers that subsequently rotate the round fruit or vegetable in the presence of an overhead UVC germicidal light source. This apparatus is limited to products, which have a shape that is round or spherical, and smooth.

(b) U.S. Patent No 4,776,267 filed March 25, 1987 by Harris (incorporated fully by reference herein) describes an apparatus in which the foodstuffs are transported on a shaker table to spread out the flow of the foodstuff in the presence of an overhead UVC germicidal light source. This apparatus includes two product turnovers as compared to the present invention which continuously tumbles and turns the foodstuff, increasing the probability that all surface area is adequately exposed to the UVC germicidal light source.

(c) U.S. Patent No 5,958,336 filed April 26, 1996 by Duarte (incorporated fully by reference herein) describes an apparatus in which objects are conveyed with UVC germicidal light sources above and below the conveyor. This apparatus has the disadvantage of the potential of shadowing, which reduces the probability that all surface areas are exposed to the UVC germicidal light source. This apparatus is for the surface sterilization of containers, which enter the "clean room" for the packaging of pharmaceutical products.

(d) U.S. Patent No 6,171,548 filed November 16, 1998 by Rose et. al. (incorporated fully by reference herein) describes a method and apparatus for sterilizing organic and inorganic matter through simultaneous exposure

to ultraviolet light energy and ultrasonic wave energy in a non-aqueous environment such as air. The apparatus is either a chamber or a conveyor belt. This apparatus has the disadvantage of not continuously tumbling and turning the product to be sterilized, thus reducing the probability of exposing all surfaces to the ultraviolet light energy.

(e) U.S. Pat. No. 4,983,411 filed Aug. 24, 1989 by Tanka teaches vacuum packing raw meat in a UV transmissible film, exposing the vacuum packed meat in its package to ultraviolet irradiation, and then shrink-wrapping the package around the raw meat in a high temperature atmosphere. Tanaka uses broad-spectrum UV-radiation, including long-wavelength radiation (300 nm and greater). Such radiation penetrates packaging film relatively easily but may not be very effective at impairing or killing microorganisms. Any such activity is likely to be non-specific, e.g. relying largely on a heating effect. Moreover, such irradiation may have deleterious effects on meat quality, e.g. associated with photochemical oxidation of lipids and/or pigments. Note that the present application addresses the sterilization of a foodstuff prior to packaging, and is applicable to products of various sizes wherein if packaged prior to sterilization, various product surfaces can be shadowed or unexposed inside the package . That is, Tanka's technique of treating a product with a surface sterilizing agent after packaging is only effective on those surfaces that are exposed through the packaging material.

(f) U.S. Pat. No. 5,597,597 filed Feb. 23. 1995 by Newman discloses a stationary "irradiation tunnel" surrounding a "support means" (e.g., a conventional conveyor, or a drum conveyor), wherein a foodstuff in the tunnel is exposed to UV. Various techniques are disclosed for presumably irradiating all sides of a foodstuff with an sufficient UV light "for reducing the microbial load, e.g. on foodstuffs, especially fresh and processed meats." However, the disclosed apparatus has the following drawbacks:

(i) The conveyor embodiments require that the product items being irradiated not be stacked on one another or bunched together on the

conveyor. Thus, some mechanism must assure the product items are spaced apart prior to the product items entering the irradiation tunnel.

(ii) The conveyor embodiments require some means of appropriately irradiating the product surfaces in contact with the conveyor. It is stated that a "wide mesh for the conveyor is preferred as this will minimize contact points between the foodstuff and the conveyor." However, the width of the mesh must be sufficiently smaller than the food product items being irradiated to retain the product items on the conveyor. Thus, for food products of substantially different sizes (e.g., shrimp or nuts versus steaks), the conveyor belt may have to be replaced with one of a different mesh, or alternatively, the conveyor may have a very fine mesh (for accommodating virtually any product), but then creating more product surface area that is not appropriately exposed to the surface sterilization agent. Additionally, in one disclosed embodiment, "guides or baffles" are disclosed for shifting the product items while resting on the conveyor". Note, however, that the action of such guides pushing the product against the friction on the conveyor belt may cause damage to fragile products. In another embodiment, multiple conveyors serially convey the product items through the tunnel wherein the product support belt for the conveyors have a different pattern contacting the product items. Numerous transfers of the product may be required to assure that all surfaces on irregular shaped free flowing products are treated (as compared to the rotating tumbling drum or screw conveyor with lifting baffles of the present invention). In yet another embodiment, there is a suggestion that the conveyor belt itself be made of a UV transmissive material. However, it is unclear how such material would maintain such a UV transmissive quality in a commercial food product setting without becoming substantially opaque due to

residue build up and/or abrasion or scratching. Moreover, even if an appropriate UV transmissive conveyor could be provided, products near the center of the conveyor may not have their surfaces adequately exposed to the UV radiation due to the shadowing of adjacent product items.

(iii) In the drum conveyor embodiments, the UV lights are positioned about the exterior of a rotatable drum conveyor. The drum conveyor is disclosed as being of "a simple grid structure" wherein the diameter of the mesh of the grid forming the walls of the drum are determined by the size of the product items to be irradiated. Accordingly, the drum mesh may preclude a substantial amount of the UV radiation from contacting the product items when, e.g., the product items are small and/or the drum grid must withstand a considerable product load (e.g., thousands of pounds). The shadowing of the mesh drum is proportional to the percent open area of the mesh as compared to the present invention where the UV lights are positioned inside the rotating drum or screw conveyor with lifting baffles, and has no shadowing on the product being treated with the exception of shadows created by the product itself. Moreover, the positioning of the UV lights appears problematic (e.g., at least those below Newman's drum, and possibly also those above the drum, depending on the drum rotational speed) for product items that cast off dirt, debris or any liquid (e.g., water) in that the UV lights will become progressively less light transmissive unless the sterilization process is repeatedly stopped so that lights can be cleaned.

Thus, it would be desirable to have a food sanitizing method and apparatus that could cost effectively be used in most commercial food processing facilities that need to reduce the microbial population on the surface of food products, wherein the method and apparatus did not have the disadvantages of the prior art as described above. In

particular, it would be desirable to have a method and apparatus for sterilizing food products: (a) in high volume, wherein the amount (volume, or weight) of the product to be sterilized is large, (b) where the food product items vary substantially in size and shape, and (c) where the apparatus does not require a specialized environment, e.g., a clean room. Moreover, it would be desirable to have a food sanitizing apparatus that can be safely cleaned by the conventional high pressure and high temperature washing cleaning techniques used in commercial food processing facilities. More particularly, when ultraviolet emitters are used as the sterilizing agent, it would be especially desirable to have protective shielding surrounding such emitters so that there is virtually no possibility of UV emitter materials (e.g., glass) commingling with the food product being sterilized and/or failing due to the high pressure, high temperature cleaning techniques used.

Objects Of The Invention

An object of the present invention to sterilize foodstuff so that it is safe for human consumption.

It is a further object of the present invention to provide surface sterilization without the use of foodstuff altering chemicals.

It is an additional object of the present invention to surface sterilize free flowing frozen foodstuff without the thawing of the frozen foodstuff. In particular, it is as object of the present invention to sterilize food products that may have substantial portions of their surfaces encased in ice. Moreover, the present invention is particularly well suited for decontaminating and/or sterilizing free flowing, fresh, dry, or individually quick frozen, particulate food products. Such dry products include, e.g., grains, nuts, rice, cereals, crackers, dehydrated products, potato chips, corn chips, etc. Individually quick frozen products include corn, peas, carrots, potatoes, French-fried potatoes, beef crumbles, fajita meats, etc. Fresh products include potatoes, carrots, beans, onions, fruits, etc.

It is also an object of the present invention to sterilize fragile foodstuff in which food product breakage creates waste. Accordingly, the present invention is applicable to raw vegetable products, which have surface bacteria, molds, and fungi existing as they

are harvested from farm locations and intended for processing operations or storage facilities for future processing.

It is also an object of the present invention to surface sterilize foodstuffs in mass production food processing plants which require protection from glass or other items from commingling with the foodstuffs. Accordingly, it is an object of the invention to provide watertightness to those components of the invention that could be easily damaged or break with exposure to high pressure and high temperature water sanitizing procedures of mass production food producing plants. In particular, such components may include: light assemblies, machine controls and electronics, and safety features required to operate within governmental regulatory requirements.

Terms and Definitions

Germicidal: As a noun this term denotes one or a combination of: a radiation energy (e.g., ultra-violet), and a substance such as ozone (possibly in combination with certain "enhancers" such as intense acoustic waves for exciting molecules on the surface of a food product thereby increasing the effectiveness of a sterilizing agent such as ultraviolet radiation on killing layered bacteria cultures) that can be applied to the surface of food products wherein there is a sterilization, sanitation, decontamination and/or disinfecting of the food product surface so that subsequently the food products can be safely consumed by humans or animals, and wherein such a germicidal does not substantially penetrate or modify the foodstuff to which it is applied. The "germicidal" as used here refers to a process and/or an output from a process for reducing (and preferably killing) micro-organisms (e.g., bacteria, viruses, fungi, molds, and/or spores) that reside on a surface of a food product, wherein such micro-organisms could compromise the safety, shelf life, appearance, nutrition, smell, taste, and/or texture of a food product. More particularly, a germicidal may be selected wavebands of ultraviolet light to inactivate one or more micro-organisms by inducing photochemical changes in the micro-organisms which render them unable to duplicate or transport and metabolize nutrients essential for their survival. The wavelength of ultraviolet

light which is most effective for inactivating micro-organisms is less then about 310 nm and more particularly between about 250 nm and about 280 nm.

UV: **This term denotes ultraviolet light in a range of approximately less than 310 nm.**

UVC: This term denotes ultraviolet light in the C band; i.e., ultraviolet radiation having a wavelength in a range of approximately 220 to 290 nanometers (nm), and more particularly approximately 250 to 280 nm, and even more particularly approximately 265 nm. The following table shows the relative effectiveness of various ultraviolet wave lengths on micro-organisms, wherein a relative germicidal effectiveness of 0.60 for a first wave length means that it is generally about half as effective as a second wave length having a relative germicidal effectiveness of 1.20.

TABLE 1 – Germicidal effectiveness.

Wave length, nm	Relative germicidal effectiveness
240	0.62
245	0.76
250	0.90
255	1.03
260	1.12
265	1.15
270	1.08
275	0.98
280	0.87
285	0.73
290	0.60

(Source: HPAC Heating/Piping/Air Conditioning, February 1996)

UVC Light Assembly: This term denotes an ultraviolet emitter assembly that includes one or more UVC light emitters. The UVC emitters are sleeved (i.e.,

encapsulated individually, as an assembly of a plurality emitters, or both) with a UVC transmissive plastic shield. The ultraviolet emitter assembly includes the emitters, a power supply or ballast for supplying electrical power to the emitter(s), and a UV light reflector. The assembly is constructed to with stand high pressure, high temperature washing activities common to food processing facilities.

Free flowing food product: This term denotes a food product or foodstuff that flows substantially as a liquid or granular substance when a force is applied thereto for, e.g., conveying the food product between destinations.

Flight(s): For a helixical disk-like structure that winds around and extents the length of an auger shaft, the term "flight" refers to a portion of the disk-like structure that winds 360 degrees around the auger shaft in a helical fashion. Thus, typically, an auger has a plurality of such flights continuously flowing into one another as they wind around the auger shaft's length so that when the shaft is rotated, the flights urge the foodstuff in the space between adjacent flights of the auger from an auger foodstuff input to an auger output.

Lifting Tumbler: This term refers to a projection extending from a foodstuff contacting surface wherein this surface is used for rotating and conveying the foodstuff. Such projections are used for lifting and tumbling, and generally exposing various surfaces of the foodstuff to a germicidal. In particular, such a lifting tumbler may be provided on the inside surface of a drum for supporting and/or lifting a foodstuff while it is being moved, e.g., by an inclination of the drum, or by a helical ribbon in the drum, or both. In another embodiment, such lifting tumblers may extend from a surface of an auger flight for supporting and/or lifting a foodstuff while it is being moved by the auger through a screw conveyor. Accordingly, when the foodstuff is no longer supported by such a lifting tumbler, the foodstuff may fall or tumble into a lower portion of the surrounding foodstuff container (e.g., a drum or auger). Thus, by providing a plurality of such tumblers on the inside surface of a foodstuff container (e.g., a drum or auger), substantially all the foodstuff surfaces may be expected to come in contact with a sufficiently dosage of a

germicidal to sterilize or decontaminate at least the surface of the foodstuff within the container.

Exposure Cycle Time: This term denotes the a desired duration of exposure to a given intensity, I, of radiation (e.g., UVC) divided by the percentage of efficiency of this intensity that is actually used for such exposure. For example, if the desired duration of exposure is 6 seconds at an intensity of I_0, and the actual exposure is 50%, then the exposure cycle time is a 12 second cycle time (= 6 seconds/50% exposure efficiency).

Watertight: This term refers to the capability of various assemblies and subassemblies of the present invention to withstand without leakage, failure or reduced effectiveness water sprays, wherein such sprays have water pressures of in a range of 1,000 psig to 1,400 psig, and more preferably 1,100 psig to 1,350 psig, and most preferably approximately 1,250 psig (pounds per square inch gage), and temperatures up to 210 degrees Fahrenheit (F), and more preferably in a range of 190 (F) to 200 (F) and most preferably approximately 195 (F).

Summary of the Invention

The present invention is directed to an apparatus for applying to a foodstuff a "germicidal" as defined hereinabove. In particular, the present invention (denoted a "surface sterilizer" herein) applies such a germicidal to a foodstuff (equivalently "food product" herein) that is being rotated and/or tumbled by at least one rotatable component so that substantially all surfaces of the foodstuff are exposed to the germicidal. More particularly, during the rotating or tumbling of the foodstuff, the present invention may transport the foodstuff in a conduit or container (more generally, a "transport") wherein: (a) the foodstuff enters the transport at a first location, (b) the foodstuff is sterilized while moving through the transport, and (c) subsequently the foodstuff exits the transport at a second location after being sterilized. In some embodiments, the transport may be a rotating drum (e.g., as the rotatable component), wherein the foodstuff enters one of the drum ends (generally while the drum is rotating) and exits the other end of the rotating drum sterilized. In other embodiments, the transport may be an auger trough, wherein a

screw type auger (as at least a portion of the rotating component) is provided in the transport for moving the foodstuff from the transport entry to the transport exit. Thus, embodiments of the present invention are well suited for the generally continuous type of food product sterilization desirable in high volume food processing facilities, wherein, e.g., individual units of a food product being concurrently sterilized will have commenced the sterilization process at substantially different times and will exit the sterilization process at substantially different times.

It is an aspect of the surface sterilizer of the present invention that as the foodstuff transverses the transport, the foodstuff is rearranged and reoriented in the transport so that there is a substantially uniform exposure to all surfaces of the foodstuff by the germicidal. Accordingly, the surface sterilizer may include various foodstuff supports that generally rotate within the transport. These supports (denoted herein as "tumblers") at least partially support the food products so that the food products are carried a greater extent upwardly, as the foodstuff progresses through the transport, than would otherwise occur without the tumblers. In particular, it is an aspect of the invention that such tumblers may be configured so that most or substantially all of the individual food product items tumble downwardly over (or under) a boundary for the food product support surfaces of the tumblers thus substantially assuring that individual food products have all their surfaces exposed to a sterilizing concentration of the germicidal. That is, the rotationally upwardly carried food products generally tumble (e.g., over or under a tumbler edge) from their tumbler supports when the supports reach an upwardly inclined position sufficient for the food products to tumble off. Thus, such tumbling causes the food products to be rearranged and reoriented for more uniform exposure to the germicidal.

In one embodiment, the tumblers may be positioned parallel to the rotational axis of the foodstuff being rotated by the rotational component(s) (e.g., a drum or an auger shaft) of the surface sterilizer. In another embodiment, the tumblers are oriented at an angle to the rotational axis of such a rotational component in which case the lifting tumblers may be angled to assist with (and/or somewhat inhibit) the movement of the food product through the trough. However, regardless of their orientation to the axis of

rotation, the tumblers may be configured so that substantially all of the individual food products tumble over (or under) the tumbler boundaries as described above.

It is also an aspect of at least one embodiment of the invention, that the tumbling action provided by the tumblers be gentle on the foodstuff or food product. In particular, it is preferred that the tumblers create a rolling motion of the food product instead of a free falling of the food product. Moreover, such tumblers may include various configurations of openings through which the food product can flow. In particular, portions of the food product that are buried may be able to exit one or more of these tumbler openings, e.g., when a rotating drum is used, such openings may be near where a tumbler attaches to the interior of the drum. Accordingly, such buried portions of the food product become more readily exposed to the UVC germicidal while the upper food product layers are being further lifted by the tumblers.

Embodiments of the present invention are especially suited to surface sterilization of large amounts (of weight or volume) of a foodstuff or food product. In particular, when sterilizing large foodstuff amounts in a continuous manner, embodiments of the invention include sensors and controllers for: (a) monitoring the amount of foodstuff within the transport, (b) increasing or decreasing the amount of foodstuff entering the transport, (c) increasing or decreasing the germicidal within the transport, and (d) starting foodstuff movement and sterilization within the transport when it is determined that it is safe for food sterilization to proceed and stopping foodstuff movement and sterilization within the transport when it is determined that it is unsafe for food sterilization to proceed.

In one embodiment, the present invention is particularly well suited for free flowing, fresh, dry, or individually quick frozen, particulate cooked or processed food products. Dry food products include spices, herbs, grains, nuts, rice, cereals, crackers, dehydrated products, potato chips, corn chips, pork rinds, beef jerky, etc. Individually quick frozen food products include corn (e.g., frozen kernel corn), peas, carrots, whole potatoes, dehydrated potatoes, figs, peppers, French-fried potatoes, beef crumbles, beef trimmings, fajita meats, shrimp, etc. Fresh food products include potato dices and shreds, carrots, asparagus, broccoli, cauliflower, onions, brussels sprouts corn, peas, cucumbers,

lettuce, beans, grains, beef, chicken, fish, shrimp, herbs, fruits, blueberries, cranberries, peeled and unpeeled tomatoes, etc.

The invention described herein may use an ultraviolet light in a C band (i.e., UVC as defined above) as a germicidal, but the invention is not limited to this germicidal. Thus, other germicidals are also within the scope of the invention such as ozone and/or combinations of individual germicidals. The source of the germicidal may be mounted in a fixed position for providing a disinfecting exposure of a substantially free flowing foodstuff (e.g., corn, peas, carrots, potatoes, French-fried potatoes, onions, beef crumbles, fajita meats, potatoes, carrots, lettuce, beans, fruits, herbs, spices, beef trimmings, beef steaks, chicken, shrimp, fish, tomatoes, etc) or tumbleable larger foodstuff (e.g., broccoli, and/or cauliflower).

A germicidal UVC light source may include a plurality UVC emitters, wherein each emitter is encased and/or coated with a plastic UVC transmissive sleeve to prevent the potential of glass contamination of the food product in the event one of emitters shatters. In some preferred embodiments, the UVC light source or assembly is watertight and able to withstand commercial food processing wash down activities where the UVC light assembly may be exposed to water pressures of 1,250 psig (pounds per square inch gage), and temperatures up to 195 degrees Fahrenheit without damage or reduced sterilization effectiveness. Moreover, the UVC light assembly may be moveably mounted on a track or hinged on a side so that the assembly can be easily accessed for maintenance (e.g., replacing UVC emitters).

Furthermore, at least when the transport includes a rotating drum, the UVC light assembly may be provided within the rotating drum. In at least some embodiments, the light assembly is generally suspended in the hollow central volume of the drum so that the light assembly does not come in contact with the foodstuff in the drum. Additionally, the light assembly may be offset from the rotational axis of the drum so that the UVC light shines more directly and/or intensely on the angular sections of the drum's interior wherein the foodstuff is expected to congregate during drum rotation. Moreover, since embodiments of the drum may rotate in either or both rotational directions, the UVC light assembly may be mounted so that the UVC light can be directed to various angular sections of the drum's interior depending on, e.g., the rotation of the drum. Furthermore, to assist in

uniformly distributing the emitted UVC across the exposed surface of the foodstuff in the drum, the UVC emitters may be distributed in the light assembly along an arc that parallels the circular contour of the drum interior.

In one embodiment, the drum may be oriented for rotation around an axis that is inclined, wherein there is a foodstuff inlet opening on the upper (higher) axial end, and a foodstuff discharge opening at the lower axial end. The drum may include tumblers inside the drum, and in particular, on the interior surface of the drum, wherein such tumblers lift and redistribute (tumble) the food products within the drum while the drum is rotating. Additionally, in one embodiment, the tumblers (also denoted "lifting tumblers" herein) may be configured for advancing the food products toward the discharge opening (i.e., drum exit), or in another embodiment, somewhat inhibiting the movement of the food product toward discharge opening. Note that tumblers for both advancing and inhibiting the flow of the food product may be included in the same embodiment of the invention.

In some drum embodiments of the invention, the tumblers provide a radial variation on the interior surface of the drum whereby: (a) food products within the rotating drum are at least partially supported on a radially inwardly projecting portion of a tumbler (alternatively, supported on a radially outwardly extending drum recess) so that the food products are carried a greater extent upwardly as the drum rotates than would otherwise occur, and (b) the upwardly carried food products generally tumble (over or under) from their tumbler support when the corresponding rotating interior portion of the drum reaches an upward inclining tangential angle from the horizontal of 30 degrees to 60 degrees.

In one embodiment of the surface sterilizer where such a rotational component is a rotating drum, a helical ribbon (e.g., with a center axis coincident with the drum rotational axis) can be attached to the interior circumference of the drum to aid with product movement through the drum. Note that such a helical ribbon can be considered an embodiment of the tumblers assuming, e.g., that the individual food products tumble over them and do not substantially only slide over the interior surface of the drum. However, such a helical ribbon can used in conjunction with other configurations of tumblers to further assist in the tumbling of the food product.

In an alternative embodiment, the foodstuff being decontaminated or sterilized may be conveyed into an inlet of a screw conveyor that includes an auger trough and a screw type auger as mentioned above. Such a screw conveyor is commonly used in the food processing industry for conveying food products as one skilled in the art will understand, wherein the trough supports the foodstuff while it is being moved by the auger within the trough. The auger includes a rotatable auger shaft about which, e.g., a continuous helical disk-like projection fixedly encircles the shaft for moving the foodstuff along the trough. In particular, such a helical disk may wrap around the auger shaft a plurality of times, wherein the food product is moved through the auger trough in food portions residing between consecutive opposing helical disk surfaces (known as "flights" and further described in the definitions section above). Embodiments of the surface sterilizer including a screw conveyor further include a germicidal emitter that sterilizes the surfaces of the foodstuff being transported and tumbled within the trough. In particular, the germicidal emitters may be positioned above an upwardly facing open portion of the trough so that the germicidal contacts at least surfaces of the foodstuff that are in a direct line of sight with the germicidal emitters. Thus, when the germicidal includes UVC, the germicidal (UVC) emitters are provided in a UVC light assembly mounted so that the UVC shines into the trough. In some embodiments, when the trough is open along its length (e.g., the trough may have a "U" shape cross section), the UVC light assembly may be mounted above (and optionally enclosing) the trough. Alternatively, when the germicidal includes ozone, the trough is likely to be entirely enclosed (except for the food entry and exit openings at its ends) thereby substantially preventing ozone from escaping the trough. Attached to the flights may be a plurality of tumblers as described hereinabove for tumbling the individual food products over or under the tumblers. Thus, such tumblers may continuously lift the food product above the auger shaft so that the lifted food product tumbles down, e.g., an opposite side of the auger shaft (or an opposite side of a tumbler) so that it is expected that substantially all surfaces of the foodstuff will be exposed to a sterilizing or decontaminating dosage of the germicidal.

Thus, in at least some embodiments of the surface sterilizer, it is an aspect that above (or more generally, adjacent to) the auger there may be one or more ultraviolet

light assemblies mounted (e.g., in a fixed position) for providing an effective sterilizing dosage of a germicidal to the foodstuff traversing the screw conveyor. In particular, the ultraviolet light assemblies may be provided, e.g., in a lid covering at least a portion of the open portion of the trough. Thus, for a germicidal that at least includes UVC, the lifting and tumbling action of the foodstuff within the screw conveyor causes substantially all surfaces of the food product to be exposed to the ultraviolet light generated by the light assemblies.

Additionally such a screw conveyor may be inclined so that the foodstuff therein moves with or alternatively against gravity.

Accordingly, in additional to the type and intensity of the germicidal utilized by the surface sterilizer, one or more of the following parameters may be important in various embodiments of the invention for determining and/or controlling the food product exposure to the germicidal: the angle of inclination of the rotational component, the rotational direction of the rotational component, the speed of rotation, the vertical distance that the food product is lifted by the tumblers, the tumbler design, any helical ribbon (e.g., provided within a rotating drum), and/or controlling the amount of food product being sterilized within the surface sterilizer at any given time . Additionally, note that when the germicidal is provided by ultra violet light assemblies (e.g., having UV emitters therein), the total wattage of the light assemblies, operating temperature of the light assemblies, and the distance of the light assembly to the foodstuff being sterilized, combined with the time in which the foodstuff is exposed to the generated ultraviolet light determines the resulting dosage of ultraviolet light in microwatts-seconds per square centimeter as one skilled in the art will understand.

Moreover, when the rotational component includes an auger, the auger pitch (i.e., the distance between auger flights), the auger rotational speed, and the length of the trough exposed to the germicidal may impact the time of food product exposure to the germicidal.

In one aspect of the invention, the diameter and the length of the rotational component may be engineered to accommodate the required throughput for a specific food product being processed.

In another aspect of the invention, the rotational component may be substantially vertical. Moreover, when a helical ribbon or an auger is utilized, such a rotational component may provide a downwardly spiraling path for the food product for exposing it to the germicidal, wherein, e.g., there are tumblers for the food product to tumble over (or under) while spiraling downward.

In another aspect of the invention, frozen foodstuff processed according to an embodiment of the present invention can be processed in such a manner so as to not substantially increase the temperature or thaw the frozen foodstuff. In particular, air of an appropriate temperature may be circulated through the rotational component to prevent the warming of frozen foodstuffs being thereby contacted. Moreover, embodiments of the surface sterilizer may be insulated to reduce food product temperature change by conduction to the ambient atmosphere through the exterior of the food product containing portion of the surface sterilizer (e.g., the drum or trough).

In some embodiments, the surface sterilizer may be jacketed to allow circulation of chilled water, chilled glycol solutions, hot water, steam, etc., for the purpose of maintaining or increasing/decreasing the temperature of the product being surface sterilized.

In some embodiments of the surface sterilizer having, e.g., a screw conveyor assembly, there is an infeed hopper wherein the surface sterilizer outputs a consistent flow of food product from a bulk supply of foodstuff to the infeed hopper. In some food processing applications, the infeed hopper and/or equipment for receiving foodstuff from the surface sterilizer may be equipped with components so that the foodstuff can be batch processed, e.g., the foodstuff can be accumulated and metered (e.g., in equal portions) into the subsequent food processing steps (e.g., packaging). .

As a further embodiment of the present invention, the transport of the surface sterilizer (e.g., an auger trough, a drum or an inner drum) may be perforated for the separation of smaller than desired particulates from food particulates of a desired size, and/or for the separation of particulate food product from a liquid, while surface sterilizing the particulate food product.

For embodiments of the invention having a rotating drum and that utilize UVC for foodstuff sterilization, the transport of the surface sterilizer (e.g., a rotating drum or an

auger trough) may have inlet and discharge UVC attenuating baffles or radiation baffle structure to thereby create a substantially enclosed housing for at least one of: (a) containing substantially all of the ultraviolet radiation within the volume of the transport, and (b) altering the ultraviolet radiation that may escape from the transport so that the escaping radiation is no longer considered a threat to humans; and therefore, meeting OSHA and related safety requirements for personnel working in the vicinity of this embodiment of the invention. In some preferred embodiments, the baffles or baffle structure is made of translucent materials that allow visibility of the food product inside the transport. Moreover, when the surface sterilizer includes an auger trough, the lid (that encloses the UVC light assemblies above or adjacent to the trough) is constructed of a UVC attenuating material, to create a substantially enclosed volume for human harmful radiation.

Additional aspects and features that may be related to the present invention may be found in one or more of the following U.S. patent applications: U.S. Provisional Patent Application Serial No. 60/393,792 filed July 3, 2002; U.S. Provisional Patent Application Serial No. 60/393,363 filed July 3, 2002 (directed to an apparatus and method for sterilizing a food product within a food processing screw conveyor); and U.S. Provisional Patent Application titled "Traveling Surface Sterilization Method And Apparatus" filed February 24, 2003 having attorney docket number 4878-4PROV, each of these patent applications are fully incorporated herein by reference.

Other features and benefits of the present invention will become evident from the accompanying drawings and Detailed Description hereinbelow.

Brief Description of the Drawings

Figs. 1A and 1B is a perspective view of one embodiment of the surface sterilizer 181 of the present invention, wherein the surface sterilizer 181 includes a rotatable drum 111 as the rotational component, and the drum 111 is floor-mounted and irradiates foodstuff with ultraviolet energy as the germicidal.

Fig. 2 is a perspective view of an embodiment of the surface sterilizer 181 to that of Fig. 1A, wherein: (i) the food product receiving end 1291 is shown receiving a food

product 115 from a conveyor 116, and (ii) a portion of the drum 111 is cut away to expose the drum's interior.

Fig. 3 is a cross sectional view of the surface sterilizer 181 of the embodiment of Figs. 1 (and also Fig. 2), wherein the view is of the cross section of the surface sterilizer that is coincident with the sectioning plane associated with the arrow P3. Note that the arrow P3 points to the side of the sectioning plane from which a viewer views the cross section.

Figs. 4A-4I shows alternative cross sectional embodiments of the tumblers 191 with their preferred direction(s) of rotation.

Fig. 5 shows an exploded view of an embodiment of the UV light assembly 145 also shown in Figs. 1 and 2.

Fig. 6 shows a more detailed view of the watertight electrical connection between the UVC lights 161 and the UV light assembly 145.

Fig. 7 is a side view of the ceiling hung surface sterilizer 181, wherein the surface sterilizer 181 includes a rotatable drum 111 as the rotational component for irradiating foodstuff with ultraviolet energy.

Figs. 8A and 8B are, respectively, a side and end view of another embodiment of the surface sterilizer 181, wherein the surface sterilizer 181 includes a rotatable drum 111 as the rotational component, and wherein the drum 111 has a square interior contour and irradiates foodstuff with ultraviolet energy.

Fig. 9 shows a partial cross sectional view of an embodiment of the rotational component wherein this component is a drum 111 having a helical ribbon 1221 therein for advancing a food product between ribbon flights.

Fig. 10A through 10D show some alternative cross sectional views of embodiments for the UVC light reflector 151 shapes that can be used with one or more UVC bulbs or lamps 161 in the rotating drum 111 or screw conveyor embodiments (e.g., Figs. 14 and 16) of the surface sterilizer 181.

Fig. 11 is a detail view of an alternative embodiment of the UVC emitter coupling having a water tight slip tube 1281.

Fig. 12 is a block diagram showing the controller 1400 and both the high level components therein for controlling the surface sterilizer 181, and various high level components with which the controller 1400 communicates.

Fig. 13 is a flowchart of the high level steps performed by the controller 1400 during food product sterilization.

Fig. 14 is a isometric view of an apparatus according to the present invention for irradiating foodstuff with ultraviolet energy, wherein a screw auger assembly 1608 is used to both transport and tumble the food product 115.

Figs. 15A-15D show various alternative cross sectional end view embodiments of the screw conveyor sterilizer 1600 showing various lifting tumbler 1620 configurations.

Fig. 16 is a side exterior view of a floor mounted embodiment of the screw conveyor sterilizer 1600 operatively associated with an infeed hopper 16 according to the present invention for irradiating foodstuff with ultraviolet energy.

Detailed Description of Specific Embodiments

The invention will now be more fully described with reference to the Figs. 1 through 16.

Figs. 1 through 3 are illustrative of embodiments of the surface sterilizer 181, wherein a rotating drum 111 is used. In particular, Fig. 1A is a perspective exterior view of the surface sterilizer 181 showing the food product output end of the surface sterilizer 181, wherein the drum 111 is used for rotatably sterilizing food products 115 provided therein. Additionally, Fig. 2 is a cut away perspective view of the food product receiving end of a substantially identical embodiment of the surface sterilizer 181 to that of Fig. 1A, wherein there is a cut away showing the interior of the drum 111. The primary difference between the embodiments of Figs. 1A and 2 is that the food product receiving end of the surface sterilizer 181 of Fig. 1A is attached to an opening in a wall 1101 of a food processing facility for receiving food products 115 through the opening, whereas in Fig. 2 the surface sterilizer receives the food products 115 from a conveyor 116, and there is a UV attenuating enclosure surrounding the drum 111 food product receiving end. Fig. 3 is a cross sectional end view of the surface sterilizer 181 of Fig. 1A (and also Fig. 2), wherein cross section of Fig. 3 is associated with the view arrow labeled "P3" in

Fig. 1A (as is further described in the Brief Description of Drawings section above). Additionally, note that the germicidal emitting component includes one or more UVC light assemblies 145, each including UVC lamps or emitters 161 (Fig. 5) and a reflector 151 used for irradiating foodstuff 115 which are conveyed through the drum 111.

The drum 111 may be substantially cylindrical in shape and the interior of the drum may be substantially UVC light reflective, e.g., the interior of the drum may be a polished surface that reflects UV light such as: polished stainless steel, polished aluminum, polished zinc, or polished coatings such as magnesium carbonate, nickel or chromium. The drum 111 may be manufactured with continuous welds to prevent the creation of crevices in which food particulates and bacteria or other micro-organisms could harbor, and thus prevent the drum from being easily sanitized. In one embodiment, for products 115 which are sensitive to temperature change, the drum 111 may be insulated with non moisture-absorbing insulation material which is sheeted over with stainless steel on the drum exterior thereby enclosing the insulation. The insulation may be selected to minimize conductive heat transfer to the exterior of the drum 111, e.g., the following insulations may be used: polyurethane, polystyrene, fiberglass, calcium silicate. Thus, for frozen food products 115 in unconditioned ambient environments, such an insulated drum 111 may prevent the sweating of the exterior of the drum caused by condensation of moisture from the unconditioned ambient environment. In another embodiment of the drum, it may be manufactured of sheet metal material with perforations or holes, which serve to separate solid materials and liquid materials, or to allow materials of a lesser particle size than desired to be separated from the larger food product 115 pieces (e.g., such smaller sized particles can fall through the drum holes). Such a perforated drum 111may be particularly useful in surface sterilization of raw whole potatoes where surface dirt can be removed by allowing the dirt to pass through the perforations in the drum. Additionally, such a perforated drum 111 may be useful for surface sterilizing vegetable products that are conveyed in water, wherein the perforations can be used to separate the water from the vegetable product by allowing the water to pass through the perforations in the drum.

Referring to the embodiments of Figs. 1-3, the drum 111 is shown with food product tumblers 191 on the inside circumference of the drum for lifting and tumbling the

food product 115 within the drum. The tumblers 191 protrude from the inside circumference of the drum 111, wherein each tumbler may protude at an angle from 15 degrees to 90 degrees (see Figs. 4A-4I for tumbler profiles) to the tangential line of the drum interior where tumbler is attached. The tumblers 191 may extent inwardly from the drum's interior surface from 1 inch to 12 inches. The tumblers 191 may have a length that is parallel to the drum rotational axis 1341. In additional embodiments, the tumblers 191 may be at an angle to the drum rotational axis in which the product tumblers 191 may assist with the movement of the food product 115 through the drum. The angle (more generally configuration or shape) and distance of protrusion of the tumblers 191 substantially determine both the amount of food product 115 lifted by each tumbler 191, and the point at which the food product tumbles downward off of the tumbler as the drum rotates. The gentile handling of fragile food products 115 which are sensitive to breakage requires a tumbler profile angle that assures the food product is always tumbling as compared to being lifted and allowed to free fall from a tumbler to the bottom of the rotating drum.

The drum 111 has substantially open ends 1291 and 1311 for, respectively, receiving and outputting food products 115. In particular, the receiving drum end 1291 receives a food product 115 from a food product infeed device 1101 associated therewith for providing a food product 115 to the drum 111. The food product 115 is deposited into the drum 111 by the product infeed device 1101 at the product receiving end 1291 at a height above the lowest inside surface of the drum wherein this height is also greater than the expected depth of the food product in the drum. The infeed device 1101 may be, e.g., a conveyor 116 (Fig. 2) such as a shaker, belt or auger conveyor, a foodstuff storage bin, or an entire food processing facility prior to packaging (as shown in Fig. 1A where the receiving end 1291 is attached to a wall opening in a chicken wing production plant for receiving processed chicken wings immediately prior to packaging). Note that, at least at the food product receiving end 1291 of the drum 111, the drum opening 1104 for receiving food products 115 may be restricted so as to prevent the input food product from spilling out of the receiving end of the drum 111. In particular, as described further below, the receiving end 1291 of the drum 111 may have an reinforcing support 1301, e.g., in the shape of an annular ring, for : (i) maintaining the drum's shape when, e.g.,

loaded with foodstuff 115, and (ii) narrowing the receiving drum opening 1104. Moreover, the distance from the outer circumference of the drum 111 to the inner circumference of this annular ring 1301 may vary depending upon: (a) the food products to be provided to the drum 111, and (b) the expected depth of the food products in the drum during operation. Preferably, this distance is effective for preventing the food products from spilling out of the receiving end 1291 of the drum, and the infeed ring 1301 may be approximately four inches to eight inches smaller in diameter than the interior diameter of the drum 111 for keeping the foodstuff 115 from falling out of the drum end 1291. Further, note that the support 1301 may also have an outside diameter that is larger than the diameter of the drum 111, and accordingly such a larger diameter provides additional reinforcement for maintaining drum alignment in relation to the rotational axis 1341 of the drum. In one embodiment, the reinforcing support 1301 may be detachable so that, e.g., drum rings 1301 having openings of different exterior and/or interior diameters may be attached to the drum end 1291. Moreover, in another embodiment, a first drum ring 1301 may be fixedly attached to the drum end 1291, and as needed (depending on, e.g., the expected depth of the food product within the drum 111), additional drum rings may be attached to (or detached from) the first drum ring to thereby decrease (or increase) the diameter of the opening 1104.

The discharge drum end 1311 outputs the sterilized food product 115 to a food product discharge subsystem 1121 adjacent thereto for receiving the food product 115 as it exits the drum 111. The discharge subsystem 1121 may include, e.g., a conveyor, a food bin, a food weighing station, or a screw type auger. Moreover, the discharge subsystem 1121 may include a food slide or chute 1123 operably attached to a frame 141 so that the food product 115 within the drum 111 exits the drum and contacts the discharge device without bruising the food product.. Optionally, the discharge subsystem 1121 may include an electromechanical gate that periodically opens to allow at least a portion of the food product 115 within the drum 111 to exit. In typical embodiments of the surface sterilizer 181, the retention time for sterilization of food product 115 in the drum 111 in the range of 2 seconds to 60 seconds depending on such parameters as the diameter and length of the drum 111, the configuration of the drum interior (e.g., the configuration of the tumblers 191), the inclination of the drum rotational axis 1341, the

amount of food product in the drum 111, the desired food product exposure to the germicidal, the shape and texture of the food product being sterilized, the UVC irradiance generated by the UVC light assemblies 145.

The drum end 1311 also has a reinforcing support 1321, to maintain the drum's shape when, e.g., loaded with foodstuff 115. Each of the drum end reinforcing supports 1301 and 1321 may be an annular metal ring whose centers are substantially in line with the rotational axis 1341 of the drum 111. The discharge reinforcing support ring 1321, in addition to acting as a reinforcement to keep the drum 111 round, has a central circular opening with an inside diameter that may be only slightly larger than the outside diameter of the drum 111 so that it can be tightly secured to the outside of the drum 111. Moreover, depending on the drum 111 length $\mathcal{L}$, embodiments of the drum 111 may have one or more additional support rings similar to support ring 1321 provided along the drum's length. Additionally, there may be a plurality of beams or rods that extend between and attached to the rings 1301, 1321 and any intermediate reinforcing rings for providing additional structural support to the drum 111.

In some embodiments, the support 1321 may be attached to the circular drum edge 1345 and thereby act as a drip ring for wet foodstuff 115, or for condensation that forms on the exterior of an un-insulated drum operating with refrigerated or frozen foodstuff. Accordingly, such a drip ring can be used for accumulating water droplets so that such waste liquid can fall free from the desired foodstuff 115 thus keeping the waste liquid from reentering the sterilized foodstuff or being retained with the sterilized foodstuff exiting the drum 111.

Regarding the structural frame 141, the drum 111 is supported from the floor by this frame which may be made of, e.g., of corrosion resistant materials such as stainless steel angles or tubes, and engineered for adequate structural strength to support the imposed loads with a minimum of deflection. Such frames 141 may be manufactured with continuous welds to (a) prevent the creation of crevices in which food particulates and bacteria could harbor, and (b) cause the frames to be easily sanitized. The frame 141 includes a rectangular cage 1346 surrounding the drum 111. On the lower horizontal beams 1347 of the frame 141 there is support structures for:

(i) a drive mechanism 171 (described hereinbelow) for rotating the drum 111,

(ii) drum support wheels 121 (described further hereinbelow),

(iii) a plurality of drum safety alignment mechanisms 1348 which in Figs. 1-3 are elbow-like projections that angle upwardly toward the drum 111 from the beams 1347 on each side of the drum; such mechanisms 1348 facilitate drum 111 alignment within the cage 1346 by, e.g., having rollers (not shown) on their free ends for rolling along the exterior of the drum 111 as it rotates so that any undesired forces that might misalign the drum from its operational position (e.g., from rotating about the axis 1341) within the cage 1346 can be dampened. Alternatively, instead of having rollers at their free ends, the alignment mechanisms 1348 may have a low friction pad or plug at their free ends that are spaced apart or offset from the drum exterior surface by a relatively small amount (e.g., 0.25 to 0.5 inches) when the drum is properly aligned about the rotational axis 1341. Thus, if the drum 111 deviates sufficiently from rotating about the axis 1314, the exterior of the drum will contact one or more of the safety alignment mechanisms 1348 for thereby at least inhibiting any further drum alignment deviations. Note that such pads or plugs are well known in the art, and may be made from such materials as Teflon or an ultra-high molecular weight polymer (UHMW). Furthermore, the offset free ends of the alignment mechanisms may have a contour that parallels the exterior of the drum 111. In other embodiments, (depending on the food processing environment) the offset free ends may be made of other materials such as: metal, or a material that does not induce sparking when it comes in contact with the exterior drum surface.

Adjacent the upper corners of the cage 1346 nearest the food product receiving end 1291, the frame 141 also supports one or more stabilization roller assemblies 1349 which limits the position of the drum 111 to a predetermined extent of the axis 1341; i.e., the roller assemblies 1349 prevent the rotating drum from traveling along the axis 1341 so that it would travel outside the cage 1346 or hit the cage during rotation. In the present embodiments of Figs. 1-3, each of the stabilization roller assemblies 1349 includes a pair of rollers 1350, wherein each of the rollers 1350 rotates about its own

shaft (not shown) that is provided within a housing 1352 which is secured to the food product receiving end upper corners of the cage 1346. For each pair of rollers 1350, one roller rolls along a recessed track 1354 on the side of the support ring 1301 facing the exterior surface of the drum extending toward the food product output end 1311, while the other roller of the pair rolls along a corresponding track (not shown) on the opposite side of the support ring 1301. The stabilization roller assemblies 1349 may be located in any of the upper and/or lower corners of the cage 1346. Additionally, such stabilization roller assemblies may be located so that the rollers 1350 roll on a track about another support ring such as the support ring 1321.

There are one or more UVC light assemblies 145 located inside the drum 111, these assemblies being supported by a light support subassembly 1351 of the structural frame 141. In one embodiment, the light support subassembly 1351 supports a light assembly mounting structure 1353, wherein the mounting structure supports the one or more UV light assemblies 145 within the drum 111. Note that in one embodiment, the mounting structure 1353 includes one or more ramps 1355 and jointed arms 1357 suspended from the ramps, wherein the light assemblies 145 hang from the lower ends of the arms 1357 and the upper ends of the arms have wheels 1359 attached thereto for rolling on the ramps 1355. Moreover, since the ramps 1355 extend beyond at least one end 1291 and 1311 of the drum 111 (in Fig. 1A, the end 1311), the light assemblies 145 can be easily removed from the interior of the drum 111 for cleaning or other maintenance (e.g., UV emitter 161 replacements).

As mentioned above, the structural support 141 also provides support for wheels 121 for supporting the weight of drum 111 such that the drum 111 can rotate on these wheels. In one embodiment, there are at least three such wheels 121 (e.g., two on one side of the drum and one on the other side of the drum), and in some embodiments, at least four such wheels (e.g., Figs. 1 and 2 show four wheel embodiments wherein a first pair of wheels is shown, and the other pair of wheels 121 support the drum on the hidden drum side).

In the embodiment of Figs. 1A and 2, the inclination angle of the drum 111 is adjusted with an adjustment screw 131 (not shown in these figures, but a corresponding screw is shown in Fig. 7 described hereinbelow) which elevates or lowers the receiving

end 1291 of the drum 111 while the discharge end 1311 of the drum 111 is fixed and situated to pivot on a point supported by the drum support frame 141. Referring to Fig. 1, inclination angle adjustment of the surface sterilizer 181 is accomplished by changing the vertical position of the drum rotational drive wheel 121 nearest the receiving end 1291 while the discharge end 1311 is in a fixed position and allowed to pivot. Accordingly, such height adjustments change the inclination of the drum rotational axis 1341, e.g., away from the horizontal, and alter the retention time of the food product 115 in the drum being exposed to the UVC light.. Moreover, it is an aspect of the invention that such drum inclination adjustments can be made while the present invention is fully assembled and operable. In one embodiment, the range of angles through which the drum 111 can be inclined is approximately 0 degrees to 20 degrees. However, it is within the scope of the present invention for greater or lesser ranges to be operably available, and in one extreme case, the inclination of the drum 111 may approach a vertical orientation.

In another embodiment, the inclination angle of the drum 111 may be adjusted with drum inclination adjustment screws 131, wherein there may be a corresponding screw 131 for each of the wheels 121 nearest the drum end 1291. In particular, each of the screws 131 may be operably connected to a corresponding one of the wheels 121 so that the screw can be used to adjust the height of its corresponding wheel and thus also adjust the height of the drum inlet 1291.

In another embodiment, one or more of the screws 131 may be threaded through a cross member (not shown) of the frame 141, wherein the cross member extends underneath the drum 111. An upper most end of the screws contact a wheel support member (not shown) also extending underneath the drum 111, wherein the wheel support member supports the wheels 121 nearest to the drum end 1291, and wherein the wheel support member is vertically moveable above the cross member. In particular, the wheel support member may rest on the uppermost end(s) of the one or more screws 131 and moves up or down in height with a height change of the uppermost end(s) of the screws. Thus, depending on how the one or more screws 131 are rotated, the height of the wheel support member (and the wheels 121 attached thereto) is adjusted up or down. One of ordinary skill in the art can readily appreciate that there are numerous ways of adjusting the inclination of the drum 111 in addition to the mechanical embodiments described

here. In particular, such inclination adjustments could be made by hydraulics, pneumatics and/or jacks of various types. Additionally, note that such inclination adjustments could be made by adjusting the relative heights of the legs 141a of the frame 141 as one of ordinary skill in the art will understand. Further, note that such adjustments can be placed at the drum end 1311 instead of, or, in combination with, drum inclination adjustments at the drum end 1291. Moreover, the inclination of the drum 111 may be electronically controlled, and the drum inclination may be altered while the drum is rotating with food product 115 being sterilized therein.

The rotational motion of the drum 111 is created by the rotational motion generated by a drive mechanism 171 (Fig. 1B), which includes, e.g., an electric, hydraulic, or pneumatic motor 173, plus an actuator (not shown). The actuator communicates with a controller 1400 (Fig. 12 and described in more detail hereinbelow) for, e.g., setting the rotational rate output by the motor 173. The rotational motion output by the motor 173 rotationally drives a pulley 1201. In one embodiment (Figs. 1A and 1B), there is a belt 1141 that securely fits around the circumference of the drum 111 and additionally around the pulley 1201 such that the rotational motion of the pulley causes the belt 1141 to travel about the drum thereby rotating the drum. Note that there are numerous other techniques for rotating the drum 111. In particular, the drive mechanism 171 may be used to rotate one or more of the wheels 121 (either through a gear box or by a direct drive configuration).

Additionally, note that the present invention may also include a braking assembly (not shown) for stopping the rotation of the drum 111, e.g., in case of an emergency. Such a braking assembly may be activated via an emergency button 1404 prominently located on or near the surface sterilizer 181 (e.g., in Fig.1 on the control box 1406 which is the junction box for substantially all electrical power to be used by the surface sterilizer 181). The braking assembly may include a braking mechanism substantially similar to a conventional disk brake such that the disk brake uses the portions of one or more of the support rings 1301 and 1321 that extend outwardly from the exterior surface of the drum 111. Alternately, a brake motor may be applied for stopping the rotation of the drum, which involves a disc friction type brake that actuates when such a brake motor is de-energized.

In some embodiments of the surface sterilizer 181 there can be one or more mechanisms to provide an even flow of food product 115 to the rotating drum 111 and/or maintaining within a desired range an amount of food product 115 within the drum. In particular, there may be one or more food input sensors for sensing when the rate of food product 115 entering the drum 111 should be increased or decreased by, e.g., slowing or increasing the rate at which the food product is delivered to the drum 111. In particular, such food input sensors may provide to the controller 1400 signals indicative of, e.g., a weight, or a volume of food product: (i) entering the drum 111, and/or (ii) at a predetermined location upstream in the food product processing flow toward the drum. The controller 1400 can then use this information to determine drum 111 utilization (e.g., the amount of food product 115 being sterilized in the drum, and/or the degree of sterilization being performed). Further description of the controller 1400 and its data inputs and outputs are provided below.

In some embodiments, food input sensor(s) may be used to detect food product falling accidentally out of the drum 111 and/or falling into the drum 111 at the receiving drum end 1291. Each such sensor may be an optical or infrared sensor (not shown) for detecting food product falling through the air. Alternatively, such a sensor may include a weight sensitive platform (not shown) that registers abrupt changes in weight greater than a predetermined amount. Such a weight sensitive sensor may be placed immediately adjacent to and below the food inlet opening 1104 of the drum end 1291.

Moreover, one or more drum capacity sensors may be provided in the drum 111 or adjacent to the drum for determining whether there is too much food product 115 in the drum, or whether the drum and the germicidal emitters have the capacity for sterilizing additional food product. For example, within the drum 111 there may be one or more downwardly directed food product depth probes 1408 (e.g., Fig. 2 and Fig. 3), wherein each such probe can easily detect contact with the food product 115 in the drum 111. In particular, the probes 1408 may detect such a food product 115 contact by sensing a force from the contact, or by sensing a positional deflection of the probe (e.g., being deflected through a predetermined angle more than a specified frequency, and/or for a predetermined time period) via contact with the in-drum food product. With one such in-drum probe 1408 (or a plurality of probes provided along the length $\mathcal{L}$ at the

same depth in the drum 111 interior), product overload can be sensed, and perhaps a damming or blockage within the drum. However, by providing a group of a plurality of such probes 1408 wherein the probes of the group are at a plurality of different depths within the drum 111 (and optionally, providing such a group of probes at various locations along the length $\mathcal{L}$ of the drum), a depth of the in drum food product 115 can be estimated. For example, if there are three such probes 1408, relatively near one another, wherein each of the probes extend to a different depth in the drum 111, then at least four food product 115 depth classifications may be estimated for the portion of the drum interior where the probes downwardly extend; i.e., a depth classification corresponding to none of the probes 1408 swinging, a depth classification corresponding to only the lowest of the probes swinging, a depth classification corresponding to at least the second to the lowest of the probes swinging, and a depth classification corresponding to at least the highest of the probes swinging. Accordingly, a "food product" overload condition is likely to exist when at least the highest of the probes 1408 is being sufficiently contacted by the in-drum food product 115, and in such a circumstance, signals may be provided to the controller 1400 so that the controller can initiate one or more of the following: (a) slow/stop the rate of food product being provided to the drum 111, and/or (b) alert an operator of the condition. Additionally, if the lowest probe 1408 does not detect contact by the in-drum food product 115, this may be indicative of either too little food product within the drum 111, or a damming/blockage within the drum. Thus, such in-drum probes 1408 can be used to detect anomalous conditions within the drum 111 such as damming or bunching (or some other blockage) of the food product 115 within the drum. For instance, if a food product 115 overload condition is detected by the probes 1408 in one portion of the drum interior, and downstream within the drum 111, a reduced amount of food product is detected, then a blockage may have occurred within the drum 111.

Some other sensors that may be used with various embodiments of the surface sterilizer 181 are:

(a) a drum weight sensor for weighing the drum 111, and thereby allowing the controller 1400 to determine the weight of the food product 115 within the drum 111;

(b) a food product weighing sensor for weighing the food product exiting and/or entering the drum 111;

(c) a temperature sensor for measuring a temperature within the drum;

(d) one or more optical or infrared sensors for sensing one or more light beams traversing the length $\mathcal{L}$ of the interior of the drum at one or more depths within the drum 111 for performing substantially the same functions as the probes 1408 described hereinabove;

(e) one or more non-contact ultrasonic distance sensors with analog outputs for sensing product depths within the drum 111 at one or more locations for performing substantially the same functions as the probes 1408 described hereinabove;

(f) one or more germicidal in-drum concentration sensors for detecting an abnormal concentration of the germicidal; e.g., when the germicidal is UV, the amount of UV light contacting the food product may be undesirably reduced due to the UV light assemblies 145 being clouded or coated with food product debris. Such sensors may be spaced apart from the one or more UV light assemblies 145, and when the sensors detect a low enough level of UV light, then it may be assumed that approximately no more than twice the amount of UV light detected is being utilized for surface sterilization of the in-drum food product 115.

Since the ends 1291 and 1311 of the drum 111 may be (and typically are) substantially open, there is the possibility (when UVC is used as the germicidal) of the UVC light escaping from the interior of the drum and damaging the eyes and/or the skin of personnel in proximity to the surface sterilizer 181. Accordingly, at least in areas where an operator and/or other personnel may be subject to such radiation, the present invention includes components so that the UVC is substantially prevented from contacting personnel about the drum 111. In particular, the UVC light may be attenuated on the infeed (i.e., receiving) end 1291 of the drum 111, and/or also on the discharge end 1311 by corresponding adjacent UVC attenuating baffles 1191 (shown in Fig. 1A as only on the discharge end 1311 and shown in Fig. 2 on the food product receiving end 1291).

Such baffles 1191 may be made of, e.g., (i) a rigid (and preferably substantially clear) UVC attenuating plastic (e.g., Fig. 1A), or (ii) a flexible (and preferably substantially clear) UVC attenuating plastic (e.g., Fig. 7 described hereinbelow) as is typically used as welding curtains for protection of eyes and skin of personnel in the area of the welding activity, or (iii) a more rigid and opaque material such as metal. In one embodiment, the baffles 1191 may be at least partially UVC reflective on their sides facing the interior of the drum 111 so that the escaping UVC light is reflected back into the drum 111. Note that when a perforated drum 111 is used, the baffles 1191 may be applied around the entire drum for the protection of eyes and skin of personnel in the area from ultraviolet rays. In one such embodiment, the UVC attenuating baffles 1191 shown in Fig. 1A may be enlarged to include the entire drum 111.

Fig. 3 is a sectional end view of the embodiments of Figs. 1 and 2. Fig. 3 shows one embodiment of the profile of the tumblers 191 on the inside circumference of the drum 111. Accordingly, the tumblers 191 lift and tumble the food product 115 in the drum 111 thereby exposing substantially all surfaces of the food product to the UVC light generated by the UVC lamp(s) or emitters 161 (Fig. 5) within the light assemblies 145. Note that it is an aspect of the present invention for the light assemblies 145 and/or the UVC lamp(s) 161 and/or their reflector(s) 151 to be tilted or obliquely oriented so that most of the UVC light is directed toward those portions of the interior of the drum 111 where the food product 115 is prone to collect while being rotated. In particular, the light assemblies 145 may be oriented so that their generated UVC light is substantially directed to an angular range (of the drum's interior) of approximately 90 to 120 degrees about the drum rotation of axis 1341, wherein this range generally extends (relative to the drum interior's lowest portion): (i) from 5 to 15 degrees against the rotation of the drum, and (ii) to an angle of 80 to 115 degrees in the direction of drum rotation.

Figs. 4A-4I show various alternative cross sectional or profile views of the tumblers 191 which may be utilized with various drum and auger screw embodiments of the surface sterilizer 181. Note that arrow 1194 shows the preferred direction(s) of drum 111 rotation for each of these alternative tumbler 191 configurations. In various embodiments, the tumblers 191 may be one of: (a) parallel to the rotational axis 1341 of the drum 111, i.e., the tumbler has a substantially uniform cross section (e.g., as shown in

Figs. 1 and/or 4A-4I) along the tumbler length, and this length is substantially parallel to the axis 1341, or (b) angled to the rotational axis 1341 of the drum to assist in the movement of the food product 115 through the drum 111 (or in some embodiments, oppose movement of the food product through the drum). Note that it is an aspect of the invention that tumblers 191 having different profiles may be interchangeably attached to the interior surface of the drum 111. In particular, the drum interior surface may include recesses for attaching or locking tumblers 191 of various heights and/or angles to the drum interior surface. Thus, a single drum 111 may appropriately tumble relatively small food product 115 items such as nuts as well as larger and/or more irregularly shaped food product items such as cauliflower. Additionally, as shown in Fig. 9, the tumblers 191 may be combined with a food product advancing helical ribbon 1221 inside the drum 111, wherein this ribbon may assist in the movement of the food product 115 through the drum.

Fig. 5 shows an exploded view of the UV light assembly 145 providing an illustration of the components included in the UV light assembly. However, note that for clarity, the number of at least some of the components is not represented in Fig. 5. The UV light assembly 145 includes a longitudinal frame member 155 (also denoted a baffle) which is the primary component to which the other structural components are attached. Additionally, the baffle 155 provides the mountings for various electrical components of the light assembly 145. In particular, the baffle 155 includes mounts for a plurality of electrical ballasts 159 for providing the desired voltage to activate the UV emitters 161, and for stabilizing the current to the UV emitters. In one embodiment, the power supplies 159 for the light assembly 145 include Steril-Aire part number 10000125, SE/SEN 16-24 Power Supply, 115 Volt as manufactured by Steril-Aire , 11100 E. Artesia Blvd., Cerritos, CA 90703. However, note that power supplies 159 are selected to be compatible with the UVC emitters 161 and operating voltage of the particular embodiment of the invention. In one embodiment, twelve such ballasts 159 may be mounted on the baffle 155.

At each end of the baffle 155 there is a corresponding one of the end supports 163a and 163b attached thereto by lug attachments 164 (only one such lug attachment is shown in Fig. 5; however, there are at least two such attachments for attaching each of

the end supports to the baffle 155). Each of the end supports 163a and 163b includes a respective plurality of UV emitter 161 holding bores 167a and 167b, wherein each of the bores secures an end of one of the emitters 161 to the light assembly 145. More precisely, there is a pair of bores 167a and 167b for securing each of the emitters 161 to the light assembly 145. Note that bores 167b are larger than the bores 167a since the bores 167b secure the electrical coupling 169 (Fig. 6) to the end support 163b, wherein the electrical coupling supplies a watertight electrical connection to its emitter 161 for supplying electrical power from one of the ballasts 159 to this emitter. In the present embodiment, there are twelve bores 167a and twelve bores 167b that are substantially equally spaced adjacent to and generally following the curve of the lower edge 175 of each of the end supports 163a and 163b. Note that the curve of the lower edges 175 (and more importantly the curve of the emitters 161) may correspond to a curve that is an offset curve from the corresponding curve of a cross section of an adjacent portion of the drum 111 interior. That is, the curve is such that each of the emitters 161 is approximately the same distance from the nearest point of the interior of the drum (e.g., between tumblers 191) on which UV light directly shines. Note, however, in another embodiment the curve of the emitters 161 may have a reduced curvature in comparison to the curvature of the drum 111 interior. In particular, the reduced curvature may parallel the expected general curvature of the foodstuff surfaces in the drum that are exposed to the UV light.

Additionally, at least the end support 163b includes holes 176 and 177, wherein electrical wiring is provided to the ballasts 159 (via hole 176) for supplying electrical power to the ballasts, and wherein electrical wiring is provided from the ballasts 159 to the couplings 169 (via hole 177) for supplying electrical power to the emitters 161. Moreover, note that the electrical power for the ballasts 159 is provided via an electrical connector 179 which provides a watertight electrical connection through an end cover 180b, this end cover being sealed tightly to the end support 163b with gasket 182b therebetween for watertightness, wherein this gasket is into a milled groove in end support 163b. Further note that there is a corresponding end cover 180a for end support 163a with a gasket 182a set into a milled groove in end support 163a therebetween for watertightness.

Each of the end supports 163a and 163b also includes a pair of mounting attachments 184 for connecting the light assembly 145 to the jointed arms 1357 so that the light assembly 145 can be mounted as shown, e.g., in Figs. 1-3.

Also attached to the baffle 155 is a reflector 151, wherein a majority of the reflector is curved to substantially parallel the curve of the emitters 161. The reflector 151 may be made of various materials. However, the side facing the emitters 161 should be a polished surface that reflects UV light such as: polished stainless steel, aluminum, zinc, or coatings such as magnesium carbonate, magnesium oxide, chromium or nickel. Note that the reflector 151 is secured to a cover 185 that provides a watertight seal with at least the end supports 163a and 163b in the following manner: The reflector 151 is set into a milled groove in each of the end supports 163a and 163b, wherein during the milled groove may be filled with a flexible food grade sealant such as silicone prior to inserting edges of the reflector 151 so that the junction of the end supports 163a and 163b and the reflector 151 is watertight. The reflector 151 is also fastened to cover 185 with screw fasteners and a gasket between the mating surfaces of reflector 151 and cover 185. Gaskets for the invention may be fabricated from materials such as: Teflon, buna N, silicone, neoprene, or another food grade rubber compound. Moreover, there may be an optional UV translucent emitter cover 199 that fits over the emitters 161 so that the emitters are between the reflector 151 and the emitter cover. Moreover, the emitter cover 199 may be attached to the reflector 151 with screw fasteners and a gasket between the reflector and the emitter cover to create the watertight connection, wherein the gasket material may include the gasket materials listed above. Furthermore, the emitter cover can satisfy the watertightness criteria as described in the Terms and Definitions section hereinabove, and additionally is scratch resistant. As an alternative (or in addition to) to the emitter cover 199, each of the emitters 161 are individually sleeved with a UV translucent material that is tightly shrink applied to the emitter tube, and which serves to contain the quartz glass of the emitter if the emitter shatters and prevent the glass from mixing with the foodstuff 115.

The watertight aspect of the UV light assembly 145 is a particularly important aspect of the invention. Accordingly, there are gaskets and/or seals between any two of the light assembly 145 components that have a seam that is exposed to the environment

exterior to the light assembly (e.g., seal 186 between electrical connector 179 and end cover 180b). In particular, such gaskets and/or seals may be composed of the gasket materials listed hereinabove.

Additionally, the UV light assembly 145 further includes a mounting clip 200 which is attached with, e.g., screw fasteners to the baffle 155. The mounting clip 200 is shaped to fit in a groove in the side of a wire terminal strip 202 that faces the mounting clip. The wire terminal strip 202 provides pressure wire connectors to connect the common power feed of the light assembly 145 to individual power feeds to each emitter power supply 159, and additionally connect each emitter power supply output to its associated emitter 161.

Referring now in more detail to the couplings 169, each such coupling includes a female threaded cap 187, a female electrical plug 189, and between these two components are a coupler 192 and a pair of O-rings 194a and 194b. The female electrical plug 189 is set into the male threaded coupler 192 and the void between the inside surfaces of the coupler 194 and the exterior side surfaces of the electrical plug 189 are filled with a two part urethane sealant that reacts when mixed to form a rubber type (e.g., elastomeric) sealant which results in a watertight assembly of the coupler 192 and the electrical plug 189. The coupler 192 with the inserted electrical plug 189 is inserted in end support 163b through a corresponding one of the bores 167b. Each of the bores 167b is machined with an internal thread to be threadably compatible with the male threads on the bore insertion portion 196 of a coupler 192 so that the coupler can be securely threaded into the bore. Alternatively, the bore 167b may be smooth and the coupler 192 fastened by a threaded nut (not shown) that is threaded onto the coupler's bore insertion portion 196 that extends through to the opposite side of the bore 167b. However, to insure watertightness, an elastomeric O-ring 194a is snuggly fitted on the bore insertion portion 196 so that when the coupler 192 (and its plug 189) are secured to the end support 163b, this O-ring is compressed between the end support and the bolt-head portion 197 of the coupler 192. With the exception of the plug 189, coupler 192, and O–ring 194a, the other components of the coupling 169 are inserted onto the emitter 161 from its end that is opposite to the emitter end 198 so that when the O-ring 194b and the threaded cap 187 are positioned on the emitter, these components are in the order shown in Fig. 6, and in

particular, so that the O-ring 194a provides a first watertight seal between the coupler 192 and end support 163b, and the O-ring 194b provides an additional watertight seal between the cap 187 and the emitter flange 201. More particularly, when the coupling 169 is fully assembled and connected to its emitter 161, the O-ring 194b tightly fits between the emitter flange 201 and a cylindrical portion interior to the cap 187 (the position of this O-ring on the emitter is shown dashed in Fig. 6).

It is an important aspect of invention for embodiments thereof to be able to operate in wide range of food processing related environments, including large variations in temperature, in humidity, in the type and size of food products being surface sterilized, and wherein personnel may or may not be proximate to the surface sterilizer 181. Regarding temperature, the UVC germicidal lamps 161 should operate effectively in food processing environments where the ambient temperature may vary from -40 degrees Fahrenheit to +120 degrees Fahrenheit. UVC emitters 161 that can operate effectively in such large temperature varying environments are available from, e.g., Steril-Aire, Inc., 11100 E. Artesia Boulevard, Unit D, Cerritos, CA 90703, these emitters known as UVC single ended sleeved emitters, Steril-Aire part number 21000301 (note, however, that the Steril-Aire part number is different for the various emitter lengths available). The Steril-Aire emitters are low pressure mercury UVC emitters, and these emitters 161 are each enclosed in a plastic material, which is shrink applied to each emitter so that the plastic material fits tightly to the emitter and is essentially a sleeve for the emitter. Note that the plastic material of such sleeves does not substantially reduce or alter the UVC light generated by the emitters. However, the plastic material is of appropriate strength to contain the glass particles in the event such an emitter 161 shatters. Note that even in embodiments of the UVC assembly 145 in which the UV emitters 161 are enclosed within a housing (e.g., provided by end covers 180a and 180b, cover 185, emitter cover 199, and the corresponding gaskets and/or seals), the use of such plastic coated emitters is likely to be required in the food processing industry to further assure that glass and/or other foreign material from the emitters do not mix with the food product 115 sterilized by the surface sterilizer 181. However, both plastic and non-plastic coated emitters 161 for embodiments of the surface sterilizer 181 are available from Steril-Aire Inc.. Moreover, the Steril-Aire Inc. single ended emitters are available in lengths of 16 inches,

20 inches, 24 inches, 30 inches, 36 inches, and 42 inches. Accordingly, the length(s) of the emitters 161 may be selected to be compatible with the length $\mathcal{L}$ of the drum 111. Thus, as shown in Figs. 1 and 2, multiple collections of such emitters 161 may be sequentially positioned throughout the length $\mathcal{L}$ of the drum 111 so that for substantially every cross section (traverse to the length $\mathcal{L}$) along the entire drum length, the cross section contacts a plurality of the emitters. Additionally, note that the Steril-Aire single ended emitters may each provide from 50 watts to 70 watts of UVC radiation, and have (on the average) a 7,500 hour life span in operational conditions.

UVC emitters 161 suitable for embodiments of the present invention are also manufactured commercially by other companies, such as Aquionics, Inc. 21 Kenton Lands Road, Erlanger, KY 41018, and American Ultraviolet, 2400 W. Cape Cod Way, Santa Ana, CA 92703.

Fig. 7 is a side view of an alternative embodiment of a rotating drum embodiment of the surface sterilizer 181, wherein components having similar functionality and structure to those recited above are labeled identically. Accordingly, the present embodiment includes a drum 111 with product tumblers 191 on the inside circumference of the drum and one or more light assemblies 145 having UVC lamps 161 with reflectors 151 for irradiating foodstuffs 115 which are conveyed through the drum 111. In the present embodiment, the drum 111 is supported from the ceiling 1500 by a structural frame 141 attached to the ceiling. The light assemblies 145 are located inside the drum 111 and are supported by a light assembly mounting structure 1353 and a light support subassembly 1351 of the structural frame 141. The rotational motion of the drum 111 is generated by the drive mechanism 171 which may include, e.g., an electric, hydraulic, or pneumatic motor 173 and which is operably connected to a controller 1400 for, e.g., setting the rotational rate output of the 173 motor and/or the rotational rate of the drum 111. The drive mechanism 171 includes drum rotational drive belt pulleys 1201 that are supported, via drive shaft 1151, by the structural frame 141. These pulleys 1201 provide the rotational motion to the drum 111. The drum 111 is suspended by drive belts 1141 which are rotationally driven by the pulleys 1201. The rotational motion of the drum 111 is created by the drive mechanism 171 wherein this motion is transferred by the drive shaft 1151 to the drive pulleys 1201, then to the belts 1141 and consequently to the drum

111. Additionally, note that since the drum 111 is suspended, in operation the drum 111 may have a tendency to swing as the foodstuff 115 tumbles within the drum. Accordingly, drum swing retarders 1161 may be provided, wherein such retarders contact the drum 111 during rotation to dampen or prevent such a swinging motion. Note that the swing retarders 1161 may contact the drum 111 with one or more wheels 1510 that are, e.g., fixedly attached to the light support subassembly 1351 wherein each wheel 1510 rolls on the drum exterior surface as the drum rotates. Moreover, there may also be stabilization roller assemblies 1349 (for simplicity, not shown in Fig. 7) which limits the position of the drum 111 to a predetermined extent of the axis 1341; i.e., the roller assemblies 1349 prevent the rotating drum from traveling along the axis 1341. Further note that the exterior of the drum 111 may include a pair of belt guides 1516 for each of the belts 1141, wherein each belt 1141 is restrained by its pair of belt guides from traveling too far in any one direction along the length of the drum 111. In particular, each belt guide 1516 may be a ridge raised above the exterior circular band of the drum 111 that is between these ridges so that the corresponding belt 1141 travels about the drum and contacts the band to which it is restricted. Of course, as in the embodiment of Fig. 1A, other techniques for rotating the drum 111 may be used such as a mechanism for rotationally driving wheels supporting the drum 111, wherein such wheels are supported on a portion of the frame 141 that is suspended underneath the drum 111.

The inclination angle of the drum 111 of Fig. 7 may be adjusted with the drum inclination adjustment screw 131, and a drum inclination pivot 1181 as it is known in the art (the pivot 1181 being, e.g., a pivot bar built into the frame 141 wherein the portion of the structural frame 141 below the pivot bar is able to pivot relative to the portion of the structural frame between the ceiling 1500 and the pivot bar). Thus, the vertical position of the drum 111 receiving end 1291 remains at a substantially fixed height while the adjustment screw 131 allows the height of the discharge end 1311 to vary in height. More precisely, adjustment of the screw 131 changes inclination of the drive shaft 1151 and the relative heights of the pulleys 1201 (Fig. 7). It is, however, within the scope of the invention that the adjustment screw 131 can be on the receiving end 1291 of the frame 141 and the pivot 1181 then will be on the discharge end 1311 of the frame 141. Moreover, as with previously described embodiments, the angle of drum 111 inclination

may generally vary between 0 and 20 degrees. However, it is also within the scope of the invention that steeper drum angles may be utilized.

Food product 115 enters the drum 111 on, e.g., an infeed conveyor 116 (more generally, infeed device 1101) and discharges on a discharge chute 1121. UVC light is attenuated on the infeed (i.e., receiving) end 1291, and on the discharge (i.e., outputting) end 1311 by the UVC baffles 1191 which in the present embodiment includes a UVC attenuating and/or reflective curtain substantially precluding the escape of UVC light from the drum 111. However, note that similar enclosures to the UVC attenuating baffles 1191 shown in Figs. 1 and 2 may also be used with the present embodiment.

Figs. 8A and 8B are, respectively, a side view and an food product discharge end view of an additional embodiment of the present invention (referred to hereinbelow as the "square drum" embodiment) which utilizes an embodiment of the drum 111 having an inner drum 203 that has square cross sectional shape. The inner drum 203 is fixedly attached to the interior of a cylindrical exterior drum 113, or alternatively, the drum 203 may be attached to the cylindrical rings 204 at, e.g., the locations of drive belt 1141 and support wheels 121, and there are UVC lamps 161 with reflector(s) 151 for irradiating foodstuffs 115 which may be gently rolled in the square drum 203. The drum 113 is supported on the floor by a structural frame 141 which in one embodiment is substantially identical to the frame of the embodiments shown in Figs. 1 and 2 (although illustrated differently in Figs. 8A and 8B). The UVC lamps 161 and reflector(s) 151 are located inside the drum 203 and are supported by an embodiment of the light support subassembly 1351 which, in the present square drum embodiment, is substantially a pair of frame cross members 1524 (one at each end of the drum 113) and preferably at least one support member 114 that extends through the inner square drum 203 and attaches to the cross members 1524. Accordingly, the reflector(s) 151 and the electrical connections for the UVC emitters 161 are attached to this support member 114. Of course, one or more embodiments of the light assembly 145, and/or the light support subassembly 1351 may also be utilized with this square drum embodiment (as well as with most other non-round shaped rotatable drums for surface sterilization). The drum 113 is supported on a plurality of wheels 121 (at least three and preferably four) wherein the wheels 121 are supported by the structural frame 141. The wheels 121 provide the rotational support for

the drum 113 on the frame 141. The inclination angle of the drum 113 may be adjusted with adjustments to one or more drum inclination adjustment screws 131 as described above for the embodiments of Figs. 1-3. Food product 115 enters the drum 203 on an infeed device 1101 and is discharged on a discharge device 1121 (e.g., a discharge chute or slide 1123). UVC light is attenuated on the infeed drum end 1291 and on the discharge drum end 1311 by the UVC attenuating baffles 1191, which in the present embodiment is similar to the UVC attenuating or reflective curtains shown in Fig. 7. The rotational movement of drum 113 is provided by the drive mechanism 171 (Figs 8A and 8) which is secured to the frame 141. The transmission of rotational movement from the drive mechanism 171 to the drum 113 is provided by the belt drive sheave or pulleys 1201 and the drive belt 1141. Food product 115 on the inside of the square drum 203 is lifted and tumbled by the flat surfaces of the drum 203 in the germicidal light created by the UVC lamps 161 and the reflector(s) 151. In an alternative embodiment, the drum 113 can be ceiling mounted in the same manner as described in Fig. 7. The square drum embodiment may be used without the product tumblers 191. However, such tumblers 191 as described above may also be used in the square drum embodiment. Note that it is also within the scope of the present invention to provide other drum geometries in which the drum has a plurality of flat sides other than four, wherein a cross section of drum 113 can be triangular, octagonal, hexagonal, etc.

A further alternative embodiment of the drum 111 is shown in Fig. 9, wherein tumblers 191 may be interspersed and combined with a food product advancing helical ribbon 1221 provided on the inside surface of the drum 111, wherein the drum rotates in the direction of arrow 117. The helical ribbon 1221 continuously wraps around the inside surface of the drum 111 so that together with the tumblers 191 (which may be at substantially right angles to the ribbon) tumble and advance the foodstuff 115 in the presence of the UVC light from the lamps 161 with reflector(s) 151 for irradiating the foodstuff 115 while the foodstuff is being turned and tumbled in the drum. Note in some embodiments, the tumblers 191 need not fully span the distance between consecutive flights of the ribbon 1221; e.g., such a tumbler may be segmented. Additionally, note that in some embodiments the helical ribbon 1221 may also be segmented (e.g., not continuous through the interior of the drum).

The drum 111 of Fig. 9 may be used with UVC lamps 161 supported in the same manner as described for the embodiments of Figs. 1-3, or Figs. 8A-8B. The drum 111 of Fig. 9 may be supported from the floor by a structural steel frame 141, as shown in Fig. 1A with all of its motors, drives and drum related supporting hardware, or it can be supported overhead as shown in Fig. 7 with all of its motors, drives and drum related supporting hardware. The helical ribbon 1221 in the embodiment of Fig. 9 can be of different pitches throughout the drum 111, or it can be of a constant pitch (i.e., the distance between the flights 1221 can be variable or constant). In an embodiment in which the pitch is shorter at the infeed end 1291, and the pitch becomes longer at a location toward the discharge end 1311, the food product 115 depth in the drum will be reduced at the point the pitch is increased.

The retention time of the food product 115 in the drum 111 for surface sterilization may be dependent upon various drum 111 parameters such as the inclination angle (if applicable) of the drum, the drum rotational speed, the configuration of the tumblers 191 (and/or any helical ribbon 1221), the amount of food product 115 in the drum, and the amount of UVC energy emitted by the UVC lamps 161. In particular, the amount of UVC energy required to be output by the UVC emitters 161 for appropriate surface sterilization of the food product 115 is substantially determined by: (i) the retention time of the food product 115 in the drum 111, (ii) the irradiance of the UVC light adjusted for operating temperature and distance from emitter to foodstuff (typically represented in microwatts per square centimeter, as one of ordinary skill will understand), and (iii) the surface area of the food product 115 that is actually exposed to the UVC light. Since such UVC irradiance may be measured in microwatts-second per centimeter squared, the table hereinbelow shows the various amounts UVC (i.e., UVC at 253.7 nm) required to destroy 90% of some common organisms.

TABLE 2 – Germicidal energy required to destroy common microorganisms.

Microorganism	Energy, µW-sec/cm²
Bacteria	
Bacillus anthracis	4,520
Bacillus megaterium	1,300
Bacillus megaterium spores	2,730
Bacillus subtilis	7,100
Bacillus subtilis spores	12,000
Corynebacterium diphtheriae	3,370
Escherichia coli	3,000
Micrococcus lutea	19,700
Micrococcus spheroides	10,000
Neisseria Catarrhalis	4,400
Proteus vulgaris	2,640
Pseudomonas aeruginosa	3,500
Pseudomonas fluorescens	8,000
Salmonella enteritidis	4,000
Salmonella typhimurium	8,000
Serratia marcescens	2,420
Shigells paradysenteriae	1,680
Spirillum rubrum	4,400
Staphylococcus albus	1,840
Staphylococcus aureus	2,600
Streptococcus hemolyticus	2,160
Streptococcus lactis	6,150
Streptococcus viridans	2,000
Yeasts	
Saccharomyces cerevisiae	6,000
Saccharomyces ellipsoides	6,000
Brewer's yeast	3,300
Baker's yeast	3,900
Mold spores	
Aspergillus flavus	60,000
Aspergillus glaucus	44,000
Aspergillus niger	132,000
Mucor racemosus	17,000
Oospora lactis	6,000
Penicillium digitatum	44,000
Penicillium expansum	13,000
Penicillium roqueforti	13,000
Rhizopus nigricans	111,000

(Source: HPAC Heating/Piping/Air Conditioning, February 1996)

Moreover, note that it is believed that to achieve a 99.99% kill rate of such micro-organisms, the irradiance required can be up to four times greater, which generally equates to four times as many emitters 161 in the drum 111. Thus, it is an aspect of present invention to be able to vary the irradiance levels within the drum 111 by, e.g., varying the number of emitters 161 that are activated during food product sterilization. For example, in the embodiments of the UVC light assembly 145 corresponding to Fig. 5, there can be up to twelve emitters 161 activated concurrently. However, various switches may be provided that activate only a portion of these emitters 161. Thus, e.g., only every other emitter 161 of the UVC light assembly 145 of Fig. 5 may be activated to thereby

reduce the UVC irradiance by half, or only every third emitter may be activate to thereby reduce the UVC irradiance to one-third. Note that such reductions may be useful in circumstances where the micro-organism(s) to be inactivated are more sensitive to UVC light (e.g., Escherichia coli above), but where items of the food product 115 have a very convoluted surface that may require additional rotational time in the drum 111 in order to assure that substantially all surfaces have been appropriately exposed to the UVC light.

Figs. 10A through 10D show some alternative cross sectional configurations of the UVC lamps 161 and their corresponding reflectors 151 (such configurations referred to as "UVC light/reflector configurations" hereinbelow). These UVC light/reflector configurations can be used in conjunction, e.g., with alternative embodiments of the UVC light assembly 145 described above, and/or with generally smaller embodiments of the rotating drum 111. Such alternative UVC light/reflector configurations may not be entirely enclosed as the UVC light assembly 145 is. However, since the UVC light/reflector configurations are also intended to withstand the sanitizing activities within a food processing facility, the power supplies and ballasts associated therewith may be remotely mounted (e.g., outside of the drum interior) in a watertight, and corrosion resistant electrical enclosure (not shown), which is referred to in the industry as a NEMA 4X electrical enclosure. However, note that the UVC reflectors 151 of such UVC light/reflector configurations are preferably manufactured of a reflective and corrosive resistant material such as those identified hereinabove (e.g., polished stainless steel, aluminum, zinc, or coatings such as magnesium carbonate, magnesium oxide, chromium or nickel). Moreover, note that the reflector 151 of Fig. 10B has a cross sectional shape that may be circular or alternatively parabolic.

Whether the reflector 151 is included in the UVC light assembly 145 of Fig. 5, or included in an alternative UVC light/reflector configuration, the reflector directs the radiated UVC light in the direction of the food product 115. The direction and range of UVC light transmitted directly from the emitters 161 to the food product 115, and/or indirectly via the reflector(s) 151 is generally toward the bottom of the drum 111. However, the direction and range may additionally be angled in the drum rotation direction wherein the food product 115 is being lifted and tumbled in the drum by the tumblers 191 and/or any helical ribbon 1221. Accordingly, the dimensions, shape and/or

adjustability of the UVC light assembly 145 (e.g., Fig. 5), and/or the UVC light/reflector configuration may be dependent on:

(a) the length, height and/or angle(s) of the tumblers 191, e.g., both the emitters 161 and the reflector(s) 151 must be spaced apart from the rotating tumblers 191 a sufficient amount so that there is no contact with the tumblers;

(b) the desired distance between the food product 115 within the drum 111 and the assembly or combination of emitter(s) and reflector(s). Note that both the emitters 161 and the reflector(s) 151 should be spaced apart from the rotating tumblers 191 (more generally, the drum interior surface and projections therefrom) a sufficient amount and so that preferably the food product 115 in the drum 111 does not become wedged or deformed due to concurrent contact with a tumbler (or the drum interior surface and projections therefrom), and one of the emitters and/or the reflector(s) (or an assembly thereof). Further note that, in general, for a drum 111 of diameter of 1 to 8 feet, the distance of the emitters and/or reflector(s) from the food product 115 may range from 2 inches to 36 inches; and

(c) the range within the drum interior where most of the food product 115 aggregates during drum rotation. For example, the higher the tumblers 191 lift the food product 115 in the direction of drum rotation, the greater the light reflection range from the reflector(s) that may be desired on the interior drum in the direction of drum rotation.

In at least some embodiments of the invention, the UVC light assembly 145 and/or another light/reflector configuration may be adjustable so that its minimum distance to the food product aggregating portion of the drum interior can be varied. For example, UVC light assembly 145 may be raised when used to sterilize broccoli and lower for sterilizing nuts. Referring to the embodiments of Figs. 1-3, such raising and lowing can be accomplished by various mechanical, pneumatic and/or electrical techniques. In particular, the vertical segment of each of the jointed arms 1357 may include concentric telescoping shafts with squeeze clamps (such as is used on bicycle seat posts) for securing the concentric shafts together at a desired length. Additionally, note

that the task of raising and lowering the UVC light assembly 145 and/or another light/reflector configuration may be performed by activating one or more motors (not shown) for, e.g., pneumatically or electrically adjusting the concentric telescoping shafts described above. Furthermore, such adjustments may be controlled by an operator providing input to the controller 1400.

In at least some embodiments of the invention, the UVC light assembly 145 and/or another light/reflector configuration may be adjustable for widening or narrowing the extent of UVC light reflected from the reflector(s) and then directly contacting the food product 115. For example, such reflectors 151 may be segmented into adjustable slats whose reflective angles can be individually varied. Moreover, the adjustment of these reflective angles may be performed electronically via the controller 1400 and motors (not shown) mounted within the UVC light assembly 145 or adjacent to such adjustable reflectors 151.

Moreover, for at least some embodiments of the invention, the UVC light assembly 145 and/or another light/reflector configuration may be adjustable on, e.g., the light support subassembly 1351 (or on the mounting structure 1353) so that the interior portion of the drum 111 receiving UVC light directly from the reflector(s) 151 can be varied by tilting the UVC light assemblies 145 (or another light/reflector configuration); i.e., such an assembly or configuration may be tiltably mounted on the light support subassembly 1351 (or on the mounting structure 1353) so that the UVC light radiated directly from the reflectors 151 can be shifted from one portion of the drum interior to another portion. However, note that in most embodiments of the invention, the UVC light support subassembly 1351 itself remains in a fixed location and position, at least some embodiments of invention are such that each UVC lamp 161 and corresponding UVC reflector 151 remain in a constant position relative to the food product 115 being lifted and tumbled within the rotating drum 111.

Fig. 11 shows details of an alternative UVC emitter coupling 169A that may be used in embodiments of the invention instead of the connector 169 of Fig. 6. In particular, the coupling 169A may be used in an alternative UV light assembly 145 to the embodiments shown in Figs. 1-3, and 5. Such an alternative UV light assembly 145 may not have the UV emitters 161 aggregately enclosed within a surrounding watertight

housing as is the case with the UV light assembly embodiments of Figs. 1-3 and 5. Thus, to prevent contamination of the food product 115 in case of an emitter 161 breaking, each of the emitters 161 must be individually enclosed in a plastic sleeve as was described previously. Furthermore, the coupling 169A includes a watertight slip tube 1281 that provides a watertight covering and seal thereby protecting the electrical connection between the UVC light female connector 1361 and the emitter 161 to be electrically connected thereto. In particular, the water tight slip tube 1281 provides watertight protection during hot water and/or chemical clean up activities that are common in food manufacturing plants. Note that such slip tubes 1281 may be made of heat shrinkable or elastic food grade rubber materials. In using the couplings 169A, the UVC emitters 161 may be attached in a fixed position to a light assembly base member (not shown). The couplings 169A allow for easy removal and cleaning, or replacement of both the emitters 161 and/or their reflector(s) 151.

Many food products are weighed, prior to packaging, on multiple select scales. Such scales are common in industry, and are often circular in configuration (when viewed from above, i.e., in plan view) such that the food product 115 is provided on each scale substantially at its center. For food processing applications using such circular select scales, the sterilization drum 111 may be ceiling mounted as shown in Fig. 7 so that the discharge chute 1121 of the sterilization drum 111 is located to deposit the sterilized food product 115 at the center of one of the circular scale areas.

Fig. 12 shows a block diagram of the controller 1400 and both the high level components therein for controlling the surface sterilizer 181, and various high level components with which the controller 1400 communicates. The controller 1400 includes a plurality of computational modules for monitoring and controlling not only the surface sterilizer 181 but additionally monitoring and controlling various sensors and devices for, e.g., providing food product 115 to the surface sterilizer and/or releasing the food product from the surface sterilizer. Fig. 12 may be considered as illustrative of various embodiments of the controller 1400 in that: (a) it is not necessary that all components shown in Fig. 12 be provided for controlling and monitoring a given embodiment of the surface sterilizer. Moreover, even thought the description of the controller 1400 and the components with which it communicates will be described in terms of a surface sterilizer

181 that includes a rotating drum as the sterilizing transport, it is believed that after one of ordinary skill in the art has understood the description of the controller 1400 hereinbelow, that such an individual could make and use a corresponding controller for other embodiments of the surface sterilizer 181 that include, e.g., a transport having an auger screw therein. Accordingly, the controller 1400 includes the following components:

(a) A food product flow controller 1412 for monitoring and controlling the amount of food product 115 provided to the surface sterilizer 181. The controller 1412 receives input from one or more food product device(s)/sensor(s) 1416 that are upstream from the surface sterilizer 181, wherein these device(s)/sensor(s) provide information as to the amount of food product 115 that is flowing toward the drum 111. In particular, such device(s)/sensor(s) 1416 may include food product weight or volume sensors. Moreover, the controller 1412 may output food product flow signals to such device(s)/sensor(s) 1416 that include mechanisms for altering the rate at which the food product 115 is provided to the drum 111. Thus, e.g., such a device 1416 may reduce or increase a food product conveyor speed providing food product to the sterilizer 181. Additionally, the controller 1412 may receive signals from a food product exit sensor(s) 1420 indicating the amount of the food product 115 that is exiting the drum 111. Such sensor(s) 1420 may, e.g., provide weight or volume measurements of the exiting food product 115. Thus, the food product flow controller 1412 may determine an estimate of the amount of food product in the drum 111. Note that in addition to, or as an alternative to, the sensors 1420, there may be one or more drum 111 weighing sensors whose output can be used for estimating the weight of food product within the drum 111.

Using such input from sensor(s) 1416 and 1420 (and/or any drum weighing sensors), the controller 1412 may, in one embodiment, predict whether the amount of food product 115 to be the drum 111 at a future time will keep the drum loaded within a predetermined range, e.g., the range being set manually by an operator, or accessed from the food product settings database 1422 described further hereinbelow, and wherein the predetermined

range may be indicative of a desirable in-drum food product weight, volume and/or depth of the food product. If the food product 115 amount is not within the predetermined range, then the controller 1412 may increase (or decrease) the food product flow rate to the drum and/or exiting the drum. Moreover, note that such a change may also require a change in the UVC irradiance of the emitters 161. Accordingly, prior to the controller 1412 requesting an increase in the food product in the drum 111 and/or a higher flow rate through the drum, the controller 1412 may request that the food product sterilization controller 1440 (described hereinbelow) determine whether an increase in UVC irradiance is necessary to continue to properly sterilize the food product 115 after such an in-drum food product increase and/or flow rate. If the food product flow controller 1412 receives notification from the food product sterilization controller 1440 that the desired surface sterilization rate can be maintained, the food product flow controller 1412 requests: (i) the food product sterilization controller to perform any necessary emitter 161 irradiance changes (perhaps starting at a future time), and (ii) instructs one or more food product flow devices to cause the food product within the drum 111 to increase and/or to cause the food product flow rate through the drum to increase.

In addition, the controller 1412 may also receive input from one or more in-drum load/blockage sensors 1424 wherein such sensors may be used with the food product exit sensor(s) 1420 to determine, e.g., the amount of food product 115 in the drum 111 (e.g., weight or volume), and/or whether there is a food product blockage within the drum 111. Such food product blockage sensors 1424 include the probes 1408, and/or non contact ultrasonic distance probes with analog outputs, and/or the optical or infrared sensors that sense light beams traversing the length $\mathscr{L}$ of the interior of the drum as described hereinabove. Accordingly, if there is a reduction in the amount of the food product 115 exiting the drum 111 and the blockage sensors 1424 are frequently or continuously triggered, then it is likely that a blockage has occurred within the drum 111. Accordingly, the food product flow controller 1412 may notify the (any) operator via the operator interface and command interpreter module

1428 (described further hereinbelow) and the operator display 1432 (e.g., a computer terminal display) of such a blockage as well as provide a message to the runtime safety controller 1436 (described further hereinbelow) which, in turn, may shut down surface sterilizer 181. Note that the food product flow controller 1412 may also receive signals from the operator interface and command interpreter 1428 instructing the controller 1412 to change the amount or rate of food product 115 in route to the drum 111. Moreover, the controller 1412 may also receive signals from a food product sterilization controller 1440 (described further hereinbelow) which monitors the food product sterilization effectiveness. In particular, sterilization controller 1440 may request the food product flow controller 1412 to increase or decrease the food product 115 flow to the drum 111 due, e.g., to a determination that the food product in the drum is being sterilized substantially faster or slower than is desired for effective sterilization and utilization of the surface sterilizer 181.

(b) The food product sterilization controller 1440 for monitoring and controlling the surface sterilization of the food product 115 within the drum 111 so that the intended degree of inactivation of micro-organisms on the food product is consistently met. In particular, the sterilization controller 1440 may activate and/or deactivate UVC emitters 161:

(i) according to any manual override instructions from an operator (via operator interface and command interpreter 1428),

(ii) automatically depending on (1) the amount of food product 115 in the drum 111 (such information received from the food product flow controller 1412), (2) the amount of UVC irradiance being currently output by the emitters 161, (3) the in-drum temperature (which may be obtained from temperature sensor(s) 1444) in that it is well known that temperature variations may effect the UVC irradiance of emitters 161, (4) in-drum water/humidity sensor(s) 1448; (5) emitter failure signal(s) 1450 that may be received from amp meter measurements of the flow of power to the emitters, and/or (6) input from the food product settings database 1422,

wherein this database includes and supplies in-drum data related to sterilization such as: (6.1) the data of Table 2 hereinabove for the micro-organisms that are desired to be inactivated on the particular food product 115 being sterilized, (6.2) the preferred range in food product weight, volume and/or depth in the drum, (6.3) the desired range in drum 111 rotation speeds, (6.4) the desired drum inclination, (6.5) the desired range of in-drum temperatures, (6.6) the desired range of in-drum humidity, and/or (6.7) the desired distance between the emitters 161 and the food product 115. Moreover, the database 1422 may store, for each of a plurality of different food products 115, corresponding collections of values such as (6.1) through (6.7).

Note that the sterilization controller 1440 may route all emitter 161 activations through the runtime safety controller 1436 described below.

Additionally, the sterilization controller 1440 may request a change to the drum 111 rotation rate in order to maintain a specified micro-organism sterilization rate (e.g., rotate the drum slower to increase sterilization due to an increased elapsed time the food product remains in the drum, and rotate the drum faster to decrease sterilization), and/or increase sterilizer 181 productivity. Thus, the sterilization controller 1440 may notify the motor interface 1456 of a (new) range of preferred drum 111 rotation speeds for the food product 115 (such signals being routed through the safety controller 1436). Also, the sterilization controller 1440 may notify a drum inclination controller 1460 of a desired range (or new range) of drum 111 inclinations for the particular food product 115 being sterilized. Note that such notifications are also routed through the safety controller 1436. Moreover, the sterilization controller 1440 may notify an operator (via the operator interface and command interpreter 1424, and the operator display 1432) of sterilization irradiance, emitter activation/deactivation, and/or emitter failures.

In at least some embodiments, the controller 1440 may retrieve, from the food product settings database 1422, sterilizer 181 operating settings for

various individual food products, which the operator may select from a menu on the operator interface 1428.

In some embodiments of the invention there may be one or more emitter output sensors 1464 that substantially directly measure the irradiance output by the emitters 161 such as described hereinabove as "germicidal in-drum concentration sensors". Accordingly, the sterilization controller 1440 receives input from such sensors 1464 for estimating the amount of irradiance to which the in-drum food product is being exposed.

As an aside note that at least some embodiments of the invention, the sterilization controller 1440 is programmed to assure a UVC irradiance of at least 1.5 to 2 times the minimum irradiance necessary to inactivate the targeted micro-organisms on the food product 115. Thus, it is assumed that variations food product sterilization factors not fully modeled will not be compensated effectively by such additional UVC irradiance.

Additionally, circumstances may arise wherein unexpected conditions occur during food product sterilization. For example, the operator or the food product flow controller 1412 may request increase in the irradiance in 3 minutes due to an increase in food product to the drum 111. However, if upon attempting to activate an additional emitter 161 the emitter fails, then if no additional UVC irradiance can be obtained, there is the possibility of food product 115 not being properly sterilized. Accordingly, the food product sterilization controller 1440 monitors such situations, and mitigates them to the degree possible by requesting one of more actions that will increase the residence time of food product 115 in the drum and/or reduce the amount of food product in the drum 111. In particular, one or more of the following tasks may be performed:

(i) the food product flow controller 1412 and/or operator is immediately notified to slow the influx of food product 115 to the drum 111;

(ii) the motor interface 1456 may be notified to slow the rotation of the drum 111; and/or

(iii) the drum inclination controller 1460 may be notified to reduce the inclination of the drum 111.

(c) The drum inclination controller 1460 for controlling and monitoring the inclination of the drum 111, wherein this module provides the interface between the (any) powered drum inclining device 1468 (e.g., pneumatic, electrical or hydraulic device(s) for changing an inclination of the drum) and the other modules of the controller 1400. Note that the drum inclination controller 1460 may receive input from a drum inclination sensor 1469, wherein such input indicates the current inclination of the drum 111. Additionally, the drum inclination controller 1460 provides communication with the operator interface and command interpreter 1428 for receiving drum 111 inclination commands and for outputting information indicating the drum's current inclination. Additionally, the drum inclination controller 1460 may communicate with the safety controller 1436 for receiving permission to change the inclination of the drum 111. For example, in an embodiment of surface sterilizer 181 wherein there are proximity detection sensors placed near the portions of the drum 111 that move when drum inclination changes, such sensors may signal the safety controller 1436 when there is an object or person that is within an unsafe zone for drum movement to commence and/or continue. Thus, the drum inclination controller 1460 may query the safety controller 1436 prior to initiating any drum inclination changes, and additionally, may act on unsolicited messages from the safety controller 1436 to terminate drum 111 inclination movement and/or reverse the drum inclination movement.

(d) The motor interface controller 1456 provides input to motor speed governor 1470 for indicating when and at what speed the motor 173 is to rotate. Additionally, the motor interface controller 1456 receives input from a motor rotation sensor 1472 for determining the current motor rotation speed. Commands for changing (and particular, increasing) the speed of the motor 173 may be routed through the safety controller 1436 first. However, operator queries (and responses thereto) regarding motor 173 related matters (e.g.,

rotational speed, and/or temperature) need not be routed through the safety controller 1436.

(e) The operator interface and command interpreter 1428 is the primary interface between the operator and the other modules of the controller 1400. In particular, the operator interface and command interpreter 1428 receives and interprets operator commands from operator command input device(s) 1472 directed to controlling various aspects of the food product 115 sterilization (e.g., changing the food product flow to the drum 111, changing the in-drum UVC irradiance, changing the drum inclination, changing the drum rotation rate, and/or terminating the sterilization process such as in an emergency stop). For example, upon receiving an operator command, the operator interface and command interpreter 1428 may interpret/parse the command, and then determine which submodule of the controller 1400 the resulting information should be directed. Thus, an signal from the emergency stop button 1404 will cause a "stop" message to be sent to the safety controller 1436, whereas a request for information related to the food product 115 flowing into the drum 111 (e.g., the weight per minute flowing into the drum) may be directed to the report/log interface 1476. Note that, as stated hereinabove, substantially all operator commands for changing an aspect of sterilization process will be first routed to the safety controller 1436 to obtain permission for the change, and subsequently, if such permission is granted, the command can then be forwarded to the submodule of the controller 1400 for performing the operator input command. However, if the safety controller 1436 determines that, e.g., a recent sensor input indicates a possible condition that would endanger personnel in proximity to the surface sterilizer 181, then the safety controller 1436 will not forward the command for processing, but will instead provide responsive communication to the operator (via the operator interface and command interpreter 1428) that the command can not be currently performed. Note that in addition to the emergency stop button 1404 (Fig. 1A), the operator interface and command interpreter 1428 may receive input from input devices 1472 such as an operator manipulateable computer pointing device (e.g.,

computer mouse), a touch screen, voice recognition software, and/or a keyboard. Additionally, the operator interface and command interpreter 1428 may receive operator commands for notifying the report/log interface 1476 (described hereinbelow) to request the generation of a report/log from the sterilization log database 1480, e.g., related to the food product 115 sterilization performed by the surface sterilizer 181. Furthermore, the operator interface and command interpreter 1428 may output surface sterilizer and/or food product related information to the operator via the operator display 1432. Such outputs may be in response to an operator query and/or a notification generated by one of the submodules of the controller 1400 as one of ordinary skill in the art will understand. In particular, the operator interface and command interpreter 1428 may provide the operator (via the operator display 1432) with a menu of selections identifying different food products 115 for sterilization. Thus, the operator may provide input to the operator interface and command interpreter 1428 of the type of food product 115 to be sterilized and the operator interface and command interpreter then instructs the sterilization controller 1440 to retrieve the default (or last used) surface sterilizer 181 operating parameter values from the database 1422 and use the retrieved values for configuring the sterilizer 181 so that this food product can be sterilized. Additionally, the operator interface and command interpreter 1428 may allow the operator to query, add, delete and/or modify the sterilization settings (e.g., such as (6.1) – (6.7) above) in the food product settings database 1422 for a selected food product 115.

(f) The report/log interface 1476 provides the other submodules of the controller 1400 with access to contents of the sterilization log database 1480. Moreover, the report/log interface 1476 allows the operator to request sterilizer 181 performance information (real time or otherwise) such as: the amount of food product 115 sterilized within a given time period, the UVC irradiance generated by the emitters 161, the estimated amount of UVC irradiance contacting the in-drum food product 115, the average and/or range of time that individual food product items remain in the drum 111, the type of food product

115 sterilized, the targeted micro-organism(s) for inactivation, the drum rotation speed, the drum inclination, surface sterilizer breakdown data (e.g., types and dates of breakdowns), and/or surface sterilizer 181 maintenance/sanitation schedules. Note that this information may be retrieved from the sterilization log database 1480. Accordingly, the report/log interface 1476 may be part of a database management system that includes programs for various predetermined reports and queries, wherein, e.g., SQL database queries are output to the sterilization log database 1480. Also, note that in addition to the various data items listed above that can be accessed via the database 1480, reports may be generated that also include such information as: the identification of the operator(s), and the sterilization productivity of the operator(s). Of course, for such reports/logs to be generated, data upon which the reports/logs are based must be accessible. Accordingly, although not shown, the controller modules 1412, 1428, 1436, 1440, 1460 and/or 1456 may output substantially all drum 111 configuration and food product sterilization related measurements to the sterilization log database 1480.

Similarly, the report/log interface 1476 may interface to the food product settings database 1422 so that, e.g., an operator can view and/or change: (i) the default settings for surface sterilization of the particular food product 115, e.g., the default micro-organisms targeted, (ii) the default UVC irradiance to be used (which may be dependent upon the amount of food product within the drum 111), (iii) the default drum rotation rate, and/or (v) the default drum inclination.

(g) The runtime safety controller 1436 is provided for assuring the safe operation of the surface sterilizer 181. In particular, the safety controller 1436 may receive signals from one or more of:

(i) Emergency stop switches 1484 such as emergency button 1404 (Fig. 1A) wherein upon receiving such a signal the safety controller 1436 shuts down all moving and UVC light generating components and additionally may apply a brake for stopping drum 111 rotation. Thus, the safety controller 1436 outputs a shutdown

or deactivate signal to the drive mechanism 170 by sending a shutdown message to the motor interface 1456 which, in turn, translates this message into the appropriate deactivate signal that is output to a motor speed governor 1470 that controls the rotational speed of the motor 173. Additionally, the safety controller 1436 outputs a shutdown or deactivate signal(s) to the UVC emitter actuator(s) 1488 so that all UVC emitters 161 are deactivated. Note, that for the UVC light assemblies 145 such actuators are: electrical contactors located in the sterilizer control box 1406. The safety controller 1436 may also output a signal to a brake actuator 1492 for applying a brake (e.g., of the braking assembly discussed hereinabove in the description of Fig. 1A) to stop drum 111 rotation. Moreover, the safety controller 1436 may also output a signal to one or more alarm and/or alarm actuators 1496 for audibly sounding an alarm to be heard by personnel in proximity of the surface sterilizer 181, and/or for activating lights for also alerting such personnel. The safety controller 1436 may also send a message to the food product flow controller 1412 requesting that the flow of food product 115 to the surface sterilizer 181 cease. Finally, the safety controller 1436 may also output data to the operator interface and command interpreter module 1428 which, in turn, transmits one or more data messages for display on one or more operator displays 1432 indicating that an emergency switch has been activated.

(ii) Baffle sensor(s) 1500 for providing signals as to whether one of the UVC light attenuating baffles (e.g., baffles 1191) at one of the drum ends 1291 and 1311 has an open portion (which should be closed, e.g., a baffle door) such that UVC light could escape and harm personnel in proximity to the surface sterilizer 181. Upon receiving a baffle sensor 1500 signal indicating that there is an open baffle portion that could otherwise be closed, the safety

controller 1436 may perform the same functions as in the case of an activation of an emergency stop switch(es) above except that: (1) there may be a reduction in the number or kind of alarms activated, (2) the data message provided on the operator display (via the operator interface and command interpreter 1438) will indicate that a baffle portion must be closed before the surface sterilizer 181 will be operable.

(iii) Motor guard sensor(s) 1504 for providing the safety controller 1436 with signals indicative of an object or person being too close to the drive mechanism 170, the rotating belt(s) 1141, and/or the wheels 121. Upon receiving such a signal, the safety controller 1436 may sound an audible alarm when a person or object is within a first proximity to the drive mechanism 170, and at a nearer proximity stop the motor 173 and apply a brake to stop drum 111 rotation. Note that such motor guard sensor(s) 1504 can be electrical proximity sensors. Moreover, the motor guard sensor(s) 1504 may be provided in the following locations: at the junction of the drive belt 1141 and the drum 111, at the drive pulleys 1201, and at the support wheels 121;

(iv) Drum rotation sensor(s) 1508 for providing the safety controller 1436 with signals indicative of the rotational speed of the drum 111. Note, that the output for the sensor 1508 should under normal surface sterilizer 181 operation substantially correspond with the output from the motor rotation sensor 1472. However, in the event that the belt(s) 1141 slip or break from the drum or the pulley(s) 1201, and/or the motor 173 malfunctions (e.g., seizes), then a significant difference between the output of the sensors 1472 and 1508 may cause the safety controller 1436 to shutdown the surface sterilizer 181.

Referring to the operation of the various surface sterilizer 181 embodiments above, the rotational motion of the drum 111 is caused by a drive motor 173 and

transferred by power transmission components (e.g., pulley(s) 1201) to the drum 111. As shown in Fig. 1A, there are drum support wheels 121 for rotatably supporting the drum. As shown in Fig. 7, the ceiling mounted embodiment includes pulleys 1201 above the drum 111 which cause the rotational motion of the drum by rotating the belts 1141 about the circumference of the drum and from which the drum 111 is suspended. However, it is within the scope of the invention and well known to those in the art that there are various methods to cause the rotational motion of the drum 111, such as timing belts, a roller chain and sprocket drives, v belts, etc. These components are_readily available from manufacturerers such as Baldor Motors and Drives, 5711 R. S. Boreham Jr. St., Fort Smith, AR 72908, , Martin Sprocket and Gear, 3100 Sprocket Dr., Arlington, TX 76015-2828, etc. The rotational speed of the drum is adjustable, e.g., via the controller 1400, and may alter the retention time of the food product 115 in the drum being exposed to the UVC light. In some embodiments, the drum 111 may be rotated using AC electrical three phase motors, wherein rotational speed is determined by using variable frequency electronic drives, which are common to those familiar with the arts. Variable frequency drives are readily available_from manufacturers such as Allen-Bradley, 1201 South Second Sr., Milwaukee, WI 53204-2410. Alternatively, variations in drum rotational speed using hydraulic motors may be accomplished with fluid flow adjustment valves, which are common to those familiar with the arts. Drum rotational speed may range from approximately one revolution per minute to approximately 120 revolutions per minute.

For a specific food product sterilization application, at some (and preferably most) of the following values are desirable to be known in order to appropriately configure an embodiment of the surface sterilizer 181 for the application: (a1) the food product 115 flow rate in, e.g., weight per unit of time (e.g., kilograms per minute), (a2) the food product 115 bulk density in weight per unit of volume (e.g., pounds per cubic foot), (a3) the range in size of the individual food product 115 items, (a4) a categorization of the food product surface texture (e.g., smooth to extremely convoluted), and (a5) the desired destruction rate for the most resistant targeted micro-organism(s) (e.g., bacteria, yeast, fungi, and/or mold spores). Such a configuration may additionally use measurements of: (b1) the drum 111 diameter (e.g., for determining an expected and/or maximum food product 115 depth within the drum), (b2) the drum length (e.g., for determining the food

product retention time within the drum and the UVC exposure time or dosage) , (b3) the tumbler 191 design (e.g., tumbler height and angle relative to the drum rotational axis), (b4) the drum inclination angle or range thereof (e.g., for determining food product retention time), (b5) the range in drum rotational speed, and (b6) the quantity, location, ambient operating temperature, and wattage of the UVC emitters 161 to provide the required dosage to all surfaces of the food product 115 to achieve the desired destruction rate of the most resistant anticipated micro-organisms. Note that using the above values and measurements settings may be initially established for surface sterilizing a particular food product at a range of food product flow rates. Thus, initial settings can be determined for the UVC irradiance (e.g., the number of emitters 161 to activate), the distance of the emitters from the in-drum food product 115 from the emitters, and the expected retention time within the drum 111 (while rotating within a particular range of rotational velocities and inclined at a particular angle).

Fig. 13 is a flowchart of the high level steps performed by the controller 1400 during food product sterilization, and in particular for determining whether a change to the food sterilization process can be safely performed. Prior to startup of the sterilizer 181, in step 1802, the safety controller 1436 identifies the components of the sterilizer that are required to be appropriately operable for safe operation of the sterilizer. Such identification may take place in two substeps: (1) identify the components that must be operable regardless of the food product being sterilized (e.g., the motor 173, various ones of sensors in Fig. 12, and the emergency button 1406), and (2) the components that must be sufficiently operable for the sterilizer 181 to operate safely, and to output a properly sterilized food product (e.g., a sufficient number of emitters 161 must be functional to obtain the desired UVC irradiance for the food product 115 that is to be sterilized). Since some embodiments of the surface sterilizer 181 may not include all of components shown in Fig. 12, the safety controller 1436 may access a sterilizer configuration data file from, e.g., the food product settings database 1422 for identifying the required components of the surface sterilizer 181 that must be operable for the safety controller 1436 to determine that the sterilizer can be operated. Once such components have been identified, step 1804 is performed, wherein a determination is made as to whether the safety controller 1436 has determined that it is safe activate, reactivate and/or reconfigure all of the identified

components of the surface sterilizer 181. Note that such components may be not currently active, or alternatively may be in an undesirable state and thus must be reconfigured. Subsequently, for each of the identified operable components, the safety controller 1436 may access a runtime data storage of descriptor (or "object" in object-oriented terminology) for determining:

(a) whether the component is currently active, available to be activated, or partially (or wholly) inoperable, and

(b) for each component that is identified as not currently active and is not identified as inoperable, the safety controller may query the component for its operational status, and/or the controller 1436 may test the component to determine its operational status and the operational status of any associated sensors.

For most computer controlled embodiments of the sterilizer 181, the safety controller 1436 will query or test activate at least some of the following components upon initial startup of the sterilizer 181: the motor 173 (via the motor speed governor 1470), the emitters 161, the (any) drum inclination motor 1468, the emergency switches 1484, the alarm(s) and/or their actuators 1496, the in-drum food product load/blockage sensor(s) 1424, the food product drum in-feed devices(s)/sensor(s) 1416, the food product exit sensor(s) 1420, the in-drum water/humidity sensor(s) 1448, the baffle sensor(s) 1500, and the motor guard sensor(s) 1504. Moreover, if actual activation is performed of, e.g., the motor 173, the emitters 161, and the drum inclination motor 1468, then substantially all the other sensors shown in Fig. 12 can be tested.

If step 1804 determines that the sterilizer 181 is unsafe to operate, then step 1808 is performed wherein various alerts, notifications and/or alarms may be initiated for indicating to the appropriate personnel that the sterilizer 181 is not safe to operate and/or can not be reconfigured as requested. In particular, if there is an operator, then the operator will be notified. Moreover, if step 1804 was performed when attempting to startup the sterilizer 181 then the startup will fail. Alternatively, if step 1804 was performed due to a request to reconfigure one or more components of the sterilizer 181 (e.g., that is currently operating), then these components will not be reconfigured. Subsequently, in step 1812, data indicative of why the safety controller 1436 would not

allow components to be activated/reconfigured is written to the log database 1480 (in Fig. 12 no data communication arrow is shown representing such communication in order to simplify the figure). Then in step 1814, the safety controller 1436 waits for additional input from, e.g., an operator or other personnel for requesting that the safety controller 1436 again perform step 1804.

Alternatively, if step 1804 determines that the sterilizer 181 is safe to operate, then in step 1816 the safety controller 1436 sends message(s) to one or more other components of the sterilizer 181 requesting activation and/or reconfiguration. Moreover, the safety controller 1436 may also output corresponding to the (any) operator indicating that the sterilizer 181 is safe to operate and/or has been reconfigured as requested, and additionally output corresponding data to the log database 1480. Subsequently, in step 1820 the safety controller 1436 waits for additional input. Note that substantially all sterilizer 181 (re)configuration commands input by the (any) operator, and (re)configuration requests by any sterilizer component (e.g., the food sterilization controller 1440, the food product flow controller 1412, the motor interface 1456) are routed back through the safety controller 1436.

Assuming the safety controller 1436 receives input, then in step 1824, this input is logged to the log database 1480. Following such logging, in step 1828, a determination is made as to whether the received input is from a sensor (or combination of sensors) indicating that a problematic event has occurred that can not be automatically corrected while operating sterilizer 181. Note that the sterilizer 181 configuration files may include data specifying which sensor input (or combinations of sensor inputs) is severe enough to result in a positive outcome from step 1828. However, at least the following are deemed sufficiently severe: (i) insufficient UVC light capacity to provide the desired sterilization, (ii) the emergency button 1404 is activated, (iii) one of the UVC baffles 1191 is not fully closed, (iv) drum 111 rotation does not correspond with motor 173 rotational speed and/or direction, (v) a motor safety guard sensor 1500 is activated, (vi) an in-drum blockage is detected. Accordingly, if the result from step 1828 is positive, then in step 1832 the sterilizer 181 is shutdown, and in step 1836 any appropriate alarms and/or notifications are initiated by the safety controller 1436. Thus, an operator will be notified, and likely any personnel that are responsible for food product 115 processing

that are upstream from the sterilizer 181 may be notified. Subsequently, in step 1840, the safety controller 1436 instructs the food product flow controller 1412 to stop the flow of the food product 115 to the sterilizer 181. Then step 1844 is performed, wherein the action(s) taken are logged in the sterilization log database 1480, and the safety controller 1436 once again waits for input (step 1820).

Returning to step 1828, if the safety controller 1436 determines that input does not identify a sufficiently severe event to warrant shutting down the sterilizer 181, then in step 1848 a determination is made as to whether the received input indicates that a correction of a previously identified anomalous event has occurred. Such a correction may be for an event that previously shutdown the sterilizer 181 such as a UVC baffle 1191 not being fully closed, an activation of the emergency button 1404, or an in-drum blockage detected. However, there are also other anomalous events that may also occur that are not sufficiently severe by themselves to warrant shutting down the sterilizer 181, such as: (i) an emitter 161 failure (which may or may not be a severe enough event to shutdown the sterilizer 181 depending on whether there is still sufficient UVC light being generated to continue sterilization or whether there is a spare emitter that can be activated while the sterilizer 181 is sterilizing), (ii) the in-drum temperature is out of range (and there is a drum temperature conditioner that can be activated), (iii) there is a reduced supply of food product 115 being provided to the drum 111, (iv) a warning proximity sensor is activated wherein an object or person has come too near to the sterilizer 181 (or a portion thereof, e.g., the motor 173) but the object or person is not so close to warrant sterilizer shutdown. However, lights and/or alarms may be activated.

If it is determined in step 1848 that a correction of a previously identified anomalous event has been performed, then in step 1852 the input is used to update the runtime sterilizer state data used by the safety controller 1436. Thus, e.g., the input may be indicative of a faulty emitter 161 being replaced with a new emitter. Accordingly, the sterilizer state data (also known as configuration data) is updated to reflect a new UVC irradiance capacity that can be generated by sterilizer 181. Alternatively, the input may be indicative of a person or object moving out of the range for activation of the above-mentioned warning sensor, and thus, e.g., any lights and/or alarms may be deactivated. The input may instead be indicative of a change in the flow of food product 115 into the

drum 111 so that the flow is again within a preferred operational range. Accordingly, since the sterilizer 181 may have been reconfigured to process the unpreferred food product flow (e.g., the drum 111 rotation, UVC irradiance and/or drum inclination may have been changed, or, the sterilizer 181 may have been configure to become intermittently inactive until one of: (i) an predetermined amount of food product 115 resided in the drum 111, or (ii) a predetermined amount of time expired), the sterilizer state must updated to reflect the more desirable food product flow rate. Subsequently, step 1804 is again performed.

Alternatively, if the result from step 1848 is negative, then in step 1856 a determination is made as to whether the safety controller 1436 has received an input from an operator. If so, then in step 1860 a determination is made as to whether the operator input is for requesting a configuration change to the sterilizer 181, or for requesting information such as operational status information. If the operator request is for information only, then the request is honored in step 1864, and subsequently steps 1844 and 1820 are again performed. Alternatively, if the operator request is for a reconfiguration of the sterilizer 181, then in step 1868 a determination is made as to whether the requested change is safe (both in terms of operation of the sterilizer 181 and to achieve the desired degree of food product 115 sterilization). Note that the processing performed in step 1868 may be substantially similar to the processing performed in step 1804 described above. Accordingly, if the safety controller 1436 determines that the requested change(s) are safe, then in step 1872 the controller 1436 sends messages to other components of the controller 1400 requesting them to perform various portions of the operator's request. Thus, an operator request to increase the food product flow through the sterilizer 181 can result in the safety controller 1436 requesting (in step 1868) that the food product sterilization controller 1440 determine an appropriate increase in the UVC irradiance for the new food product flow rate and subsequently return to the safety controller: (i) a request for activation of a corresponding number of additional emitters 161, and (ii) a new drum 111 rotation speed and/or a new drum inclination. Thus, once the safety controller 1436 determines that the responsive output from the food product sterilization controller 1440 is safe and within the capability of the sterilizer 181, then (in step 1872) the safety controller forwards and/or generates the appropriate messages to the

UVC emitter actuator(s) 1488, the motor interface 1456 and/or drum inclination controller 1460 to accomplish the operator's request. Then, after step 1872, steps 1844 and 1820 are again performed. Thus, an input from an operator may receive preference over sterilizer 181 operational parameter values determined by, e.g., the food sterilization controller 1440.

Alternatively, if (in step 1868) the safety controller 1436 determines that the operator's request is unsafe, then in step 1876 the operator is alerted that the request is unsafe, and preferably a description of why is also provided to the operator.

Returning now to step 1856, if the result from this step is that the input is not from the operator, then in step 1880 a determination is made as to whether the input is from another module of the controller 1400 wherein the input was not initiated by an operator. In particular, since the controller 1400 may provide various capabilities for automatically reconfiguring the sterilizer 181, step 1880 is for identifying such automatic reconfiguring requests. If step 1880 determines that the request was really a result of a previous operator request, then step 1868 is again performed for determining which one of the steps 1872 and 1876 should be performed. Alternatively, if the input request is automatically generated by another one of the controller 1400 modules (e.g., the food product sterilization controller 1440), then in step 1884 a further determination is made as to whether the input is for requesting a change in the configuration of the sterilizer 181. If so, then in step 1888 a determination is made as to whether the automatic reconfiguration is acceptable to the operator. Note that it is an aspect of at least some embodiments of the controller 1400 that the operator can request to view and accept or reject at least some of the automatic configuration changes generated by the controller 1400. Such operator intervention allows the operator to provide input to override (or receive preference over) certain automatic configurations (e.g., the amount of UVC light emitted, the drum 111 rotation rate, and/or the drum inclination) and thereby insert operator experience and intelligence into the control of the sterilizer 181. Thus, the operator may be able to set a minimum UVC irradiance that is above the setting typically used on the particular food product 115 being sterilized and increase the drum 111 rotation rate (e.g., due to a backlog in food product 115 that must be sterilized). Accordingly, if the food product sterilization controller 1440 requests a reduced UVC

irradiance and drum rotation rate below what the operator specified, then the request will not be honored, and instead the operator may be notified of the controller 1440 request (step 1892). Alternatively, if in step 1888 it is determined that the automatic reconfiguration is acceptable to the operator (either due to the operator not supplying a constraint applicable to the current automatic reconfiguration request, or due to the request satisfying such an operator additional constraint), then step 1868 and steps following are performed as described above.

Returning to step 1884, if it is determined that the input from another module of the controller 1400 is not a request of reconfiguration of the sterilizer 181, then in step 1896 the request is honored and steps 1844 and 1820 are again performed.

It is important to note that the controller 1400 may be used to control a plurality of sterilizers 181. Thus, a large food processing facility may operate a two or more sterilizers 181 and there may be a single controller 1400 controlling both sterilizers. A single controller 1400 controlling a plurality of sterilizers 181 can be particularly beneficial in that if the controller can route a food product 115 from one sterilizer 181 to another sterilizer, then the food processing operation is not as sensitive to a malfunction of a sterilizer in that the controller can reroute the food product to another one of the sterilizers and thus food processing is not halted.

The following examples illustrate various uses and configurations of the sterilizer 181. Note that drum 111 rotation rate and inclination in these examples may be controlled by an embodiment of the controller 1400 for maintaining the desired degree of food product surface sterilization.

<u>Example 1: French Fried Frozen Potatoes in a Rotary Drum</u>

Frozen, partially fried, shoestring French fried potato strips are to be surface sterilized prior to being provided to a multiple select scale unit, which is circular from a plan or overhead view. Since this food product is to be introduced to the center of the scale unit, an embodiment of the sterilizer 181 which is supported from above (as in Fig. 7) is selected to facilitate the drum 111 being above the multiple select scale. Assuming the potato strips are frozen, and are being sterilized in an unconditioned ambient atmosphere, the drum 111 may be insulated to prevent condensation on the exterior of the

drum, wherein the condensation could drip onto the potato strips on the multiple select scale. The flow rate of the potato strips through the drum 111 is limited by the scale to no more than 50 weighments per minute of 6.5 pounds per weighment, or a flow rate of 325 pounds of potato strips per minute (50 weighments/minute * 6.5 lbs/weighment). Bulk density of the potato strips is 19 pounds per cubic foot; therefore, the volume flow rate is 17.1 cubic feet per minute (325 lbs/minute * 1 ft^3/19 lbs).

The sterilizer 181 is configured to kill 99% of Listeria monocytogenes bacteria at a UVC dosage of 19,000 microwatts-seconds/centimeter squared. At this UVC dosage, the exposure time is expected to be 8 seconds for each surface of each of the tumbling potato strips. UVC irradiance sterilization efficiency is reduced to 33% to assure all surfaces of each potato strip are adequately exposed to the UVC germicidal radiation. Therefore, the exposure cycle time for the flow of potato strips through the drum 111 may be no less than 24 seconds (8 seconds exposure * 1/0.33 efficiency). At a volume flow rate of 17.1 cubic feet per minute, and a 24-second exposure cycle time, the volume of potato strips per exposure cycle is no more than 6.8 cubic feet/exposure cycle (24 seconds/exposure cycle * 1 minute/60 seconds * 17.1 ft^3/minute). A drum 111 having a diameter of 48 inches and a drum length of 8 foot long is selected, wherein there are six equally spaced tumblers 191 about the interior surface of the drum 111. The tumblers 191 within the drum 111 are selected to be 4 inches in height. Thus, a food product average depth of no more than 4 inches for the potato strips is preferred due to the height of the tumblers 191. Thus, when the potato strips are being tumbled within the drum 111, they are lifted or contacted by at least two of the six tumblers 191 at all times. The depth of potato strips in the bottom 60 degrees of the drum 111, from the 6:00 position to the 4:30 position assuming a counter clockwise rotational direction, is anticipated to be 4 inches. Due to the tumbling action of the potato strips, the depth as the drum 111 rotates from the 4:30 position to the 3:00 position, assuming a counter clockwise rotational direction, is anticipated to average approximately 2 inches. Therefore, the average cross sectional depth of the potato strips in the drum 111 is 3 inches. With the drum 111 being 8 feet long, the maximum quantity of potato strips in each cycle is equal to 8.4 cubic feet (3.14 * 48 inch * 1 ft/12 inches * 120 degrees/360 degrees * 8 ft * 3 inches * 1 ft/12 inches). Since 8.4 cubic feet is greater than the volume of potato strips per exposure

cycle (i.e. 6.8 cubic feet/exposure cycle), it is believed that the drum configuration will be adequate for the expected flow rate of potato strips. The exposure area of the potato strips in the drum 111 at an average product depth of 3 inches is approximately 117 square feet (3.14 * (48 inches-6 inches) * 1 ft/12 inches * 120 degrees/360 degrees * 8 ft * 4 times) based on 120 degrees of the inside drum radius, reduced by the average depth of the potato strips for an effective diameter of the potato strips exposed to the UVC light assembly 145, by 8 feet long by four times to account for the four sides of the tumbling French fry potato strips within the drum, at least one of these sides exposed to the UVC light at any time. Assume that a quantity of (24) UVC emitters 161 are selected at 24 inches long each, wherein these emitters are mounted within the drum 111 so that they are arranged to be offset from the exposed potato strips by 6 inches, or a range of 9 to 10 inches from the inside radius of the drum. Further assume that the UVC energy level of each emitter 161 is 50 watts, and that this energy level is de-rated to 80% energy for the refrigerated ambient temperature inside the drum caused by the flow of the frozen potato strips, and additionally de-rated to 40% due to the distance from the emitters to the exposed potato strips. Therefore, the effective energy contacting the potato strips after the cumulative adjustments for temperature and distance is 16 watts/emitter (50 watts/emitter * 0.8 temperature derate * 0.4 distance derate), or a total of 384 watts (16 watts/emitter * 24 emitters) from the 24 emitters. Thus, UVC energy for irradiating the potato strips is approximately 28,263 microwatts-seconds/cm^2 (384 watts * 8 seconds * 1/117 ft^2 * 1 ft2/929 cm^2 * 1,000,000 uw/w) resulting in a safety factor of 1.5 for the 99% target kill rate of Listeria monocytogenes. Inclination angle and drum rotational speed are adjusted so that the potato strips indeed flow through the drum with a 24 second exposure cycle time. Since the French fried potato strips were partially fried in 350 degree Fahrenheit oil prior to freezing; therefore, the interiors of the potato strips have been thermally sterilized. Accordingly, with the application of the surface sterilization process provided by the sterilizer 181 immediately before the packaging of the potato strips, any bacteria that re-contaminated the surface of the potato strips will be killed or inactivated at a 99% destruction rate. Therefore, the potential for potato strip waste, recall from market, bio-terrorism and consumer illness from consumption of contaminated potato strips is greatly reduced. In recent years, improvement in the testing

and detection of bacteria in foodstuffs have provided for the detection of much smaller concentrations of bacteria; therefore, due to increasingly smaller amounts of detected bacteria, there has been increased cost to the food processing industry associated with product waste, recalls, and consumer claims. The present invention as demonstrated in this example substantially solves surface contamination of food products.

Example 2: Raw Potatoes to a Potato Storage in a Rotating Drum

Raw potatoes are to be surface sterilized after being harvested from an agricultural field, and prior to being provided to a storage building. Since the potatoes are delivered with a truck, an embodiment of the sterilizer 181 which is supported from the floor or ground level (as in Fig. 1A) is selected. Since the potatoes are harvested as a root crop from underground in an agricultural field, an embodiment with a perforated drum 111 is selected to separate any loose dirt from the potatoes. Attenuating baffles 1191 are installed around the entire sterilizer 181 to contain the UVC light used with the perforated drum 111. The sterilizer 181 is to be integrated into an existing series of equipment, which receives the potatoes from the transport truck, removes dirt and vines, and conveys the potatoes into a bulk storage building. The potato flow rate for unloading transport trucks into the storage building is limited to no more than 160,000 pounds of potatoes per hour based on transport truck unloading capabilities. Bulk density of the raw potatoes is 40 pounds per cubic foot; therefore, the volume flow rate is 67 cubic feet per minute (160,000 lb/hr * 1 hr/60 minutes * 1 ft^3/ 40 lb).

The sterilizer 181 is configured to kill 90% of Aspergillus niger mold spores at a UVC dosage of 132,000 microwatts-seconds/centimeter squared. At this UVC dosage, the exposure time is expected to be 8 seconds for each tumbling potato. UVC irradiance sterilization efficiency is reduced to 33% to assure all surfaces of each potato are adequately exposed to the UVC germicidal radiation. Therefore, exposure cycle time for the flow of potatoes through the drum 111 may be no less than 24 seconds (8 seconds exposure * 1/0.33 efficiency). At a volume flow rate of 67 cubic feet per minute, and a 24 second exposure cycle time, the volume of potatoes per exposure cycle is no more than 27 cubic feet/exposure cycle (24 seconds/exposure cycle * 1 minute/60 seconds *67 ft^3/minute). A drum 111 having a diameter of 6 feet and drum length of 12 feet is

selected, wherein there are six equally spaced tumblers 191 about the interior surface of the drum 111. The tumblers 191 within the drum 111 are selected to be 6 inches in height. Thus, a food product height of no more than 6 inches for the potatoes is preferred due to the height of the tumblers 191. Thus, when potatoes are being tumbled within the drum 111, they are lifted or contacted by at least two of the six tumblers 191 at all times. The depth of potatoes in the bottom 60 degrees of the drum 111, from the 6:00 position to the 4:30 position assuming a counter clockwise rotational direction, is anticipated to be 6 inches. Due to the tumbling action of the potatoes, the depth as the drum 111 rotates from the 4:30 position to the 3:00 position, assuming a counter clockwise rotational direction, is anticipated to average approximately 4 inches. Therefore, the average cross sectional depth of the potatoes in the drum 111 is 5 inches. With the drum 111 being 12 feet long, the maximum quantity of potatoes in each cycle is equal to 31cubic feet (3.14 * 6 ft * 120 degrees/360 degrees * 5 inches * 1 ft/12 inches * 12 ft). Since 31 cubic feet is greater than the volume of potatoes per exposure cycle (i.e. 27 cubic feet/exposure cycle), it is believed that the drum configuration will be adequate for the expected flow rate of potatoes. The exposure area of potatoes in the drum 111 at an average product depth of 5 inches is approximately 130 square feet (3.14 * (72 inches- 10 inches) * 1 foot/12 inches * 120 degrees/360 degrees * 12 ft *2), wherein this is based on: (i) the potatoes occupying 120 degrees of the inside radius, (ii) the radius to the potatoes is reduced from the drum inside radius by the average depth of the potatoes for an effective diameter of 62 inches for the potatoes exposed to the UVC light assembly 145, (iii) the drum being 12 feet long, and (iv) a factor of two to account for the oval shape of the potatoes providing a contoured profile in the drum 111. An oval potato that is 2 inch diameter by 4 inches is approximately 4 ounces or 0.25 lb each. Using the bulk density of 40 lb/ft^3 and 27 ft^3 per exposure cycle, there are 1080 lbs of potatoes per exposure cycle (40 lb/ft^3 * 27 ft^3/exposure cycle), or 4320 potatoes per UVC exposure cycle at 4 ounces per potato (1080 lbs/exposure cycle * 16 oz/lb * 1 potato/4 oz). If each potato has an exterior surface area of 15.5 in^2, then the total potato surface area per exposure cycle is 465 ft^2 (4320 potatoes/exposure cycle * 15.5 in^2/potato * 1 ft^2/144 in^2). Assuming 130 ft^2 of this area is exposed to the germicidal light at any given time, this equates to 28% of the available area is exposed to the light, which is approximately equal to the 33%

irradiance sterilization efficiency (ratio of 33%/28% equals 1.2, which compares to the safety factor in the calculation of UVC energy for irradiating the potatoes). On harvested potatoes, the percentage of available area will increase due to the larger potatoes randomly mixed with the smaller potatoes as compared to the above evaluation based on all smaller 4 ounce potatoes. Initially assume that a quantity of (240) UVC emitters 161 are selected at 24 inches long each, wherein these emitters are mounted within the drum 111 so that they are arranged to offset from the exposed potatoes by 6 inches, or a range of 11 to 12 inches from the inside radius of the drum. Further, assume the energy level of each emitter 161 is 50 watts, and that this energy level is de-rated to 80% energy for the refrigerated ambient temperature inside the drum 111 during fall or winter operations, and additionally de-rated to 40% due to the distance from the emitters to the potatoes. Therefore, the effective energy contacting the potatoes after the cumulative adjustments for temperature and distance is 16 watts/emitter (50 watts/emitter * 0.8 temperature derate * 0.4 distance derate), or total 3,840 watts from the 240 emitters. Thus, UVC energy for irradiating the potatoes is approximately 254,367 microwatts-seconds/cm^2 (3,840 watts * 8 seconds * 1/ 130 ft^2 * 1 ft^2/929 cm^2 * 1,000,000 uw/w), which is sufficient (i.e. more than the dosage of 132,000 microwatts-seconds/cm^2), resulting in a safety factor of 1.9 for the 90% target kill rate of Aspergillus niger. Inclination angle and drum rotational speed are adjusted so that the potatoes indeed flow through the drum with the 36 second exposure cycle time for the 18 foot long drum 111. With application of the sterilizer 181 immediately prior to the storage of the potatoes, there is a reduction of mold, fungi, and bacteria on the surface of the potatoes. Note that such a reduction in potato surface micro-organism contaminates is believed to reduce damage in stored potatoes since mold, rot, and spoilage grows and expands substantially from such potato surface contaminates during the storage of the potatoes. Further note that a single one of the potato surface micro-organism contaminates, the silver scurf disease (a surface fungi found on potatoes) was estimated to have caused 7 to 8.5 million dollars of damage to the Idaho fresh pack potato industry based on a 1993 University of Idaho economic assessment. Accordingly, the present invention will provide the potato industry with a method and apparatus to minimize costs associated with surface molds, fungi, and bacteria on stored potatoes.

A second embodiment of the surface sterilizer 181 will now be described with reference to the figures 14 through 16.

Fig. 14 is a isometric view of a screw conveyor embodiment of the surface sterilizer 181 (denoted herein as screw conveyor sterilizer 1600) having a trough 1604 with an auger assembly 1608 therein. The auger assembly 1608 includes an auger shaft 1612, a plurality of auger flights 1616, and a plurality of lifting tumblers 1620 (that perform substantially the functions within the screw conveyor sterilizer 1600 as the tumblers 191 perform in the drum surface sterilizer 181 embodiments described above). The auger shaft 1612 has a longitudinal extent that traverses substantially the entire length of the trough 1604 (also denoted as a "transport" in, e.g., the Summary section above) from a food product infeed device 1624 to a food product discharge device 1628. Each of the auger flights 1616 spans substantially an entire cross sectional extent of the trough 1604 (such cross sectional extent being traverse to the length of the trough). Moreover, each auger flight 1616 is obliquely angled relative to the longitudinal extent of the auger shaft 1612 and is fixedly attached thereto so that when the auger shaft 1612 rotates about an axis 1632 coincident with the shaft's longitudinal extent, the auger flights urge the food product 115 between adjacent flights toward the discharge device 1628. There may be a plurality of the lifting tumblers 1620 between the flights 1616, wherein the tumblers 1620 both lift and tumble the food product 115 while the flights facilitate in conveying the food product toward the discharge device 1628 and, importantly, also facilitate in exposing additional surfaces of the food product to a germicidal such as UVC light provided by one or more UVC emitters 161 in combination with a lid/reflector subassembly 1636 mounted over the trough 1604 and the auger assembly 1608. That is, emitters 161 generate the UVC light and the lid/reflector 1636 has a UVC reflective surface (such as the reflective surfaces described hereinabove) that face the emitters for directing the UVC light toward the food product 115 that is conveyed, lifted, and tumbled through the screw conveyor sterilizer 1600. Moreover, note that the lid/reflector subassembly 1636 may be hinged to one side of the top of the trough 1604 so that this subassembly can serve to reliably enclose the food product 115 within the screw conveyor sterilizer 1600 (when closed on top of the trough 1604), and

provide access to the emitters 161 and/or the interior of the screw conveyor sterilizer 1600 for, e.g., emitter replacement, reflector cleaning, and/or trough 1604 cleaning. Additionally, note that the emitters 161 be may fully enclosed in a watertight emitter enclosure substantially similar to the UVC light assembly 145 described hereinabove. However, instead of the emitters 161 being in a convex arrangement within the UVC light assembly 145, the emitters for the screw conveyor sterilizer 1600 may be in a substantially planar arrangement, or the emitters may be in a concave arrangement within the emitter enclosure so that the emitters generally follow the contour of the reflective surface 1640 of the lid/reflector subassembly 1636.

During operation of the screw conveyor sterilizer 1600, the rotational motion of the auger assembly 1608 is created by a drive mechanism 1644 (not shown, but which is well known in the art). At the ends 1648 of the trough 1604 there are food product enclosing ends (known in the art as "end bells") which prevent the food product 115 from spilling out the ends of the trough 1604. In particular, there is an end bell 1652 at the food product input end of the trough 1604, and there is an end bell 1656 at the food product output end of the trough 1604. Additionally, there are auger support bearings 1660 mounted on each end bell , wherein each end bell and it's attached bearing 1660 provides the functionality for holding the auger assembly 1608 so that it rotates about the axis 1632 in the trough 1604 as one of ordinary skill in the art will understand. Moreover, each end bell 1652 and 1656 is supported within the trough ends as one of ordinary skill will understand. The food product 115 enters the infeed device 1624 falls through an opening 1664 in the bottom thereof into the trough 1604 wherein it is tumbled (via tumblers 1620) while being transported the length of the trough to the opposite end 1648. When this opposite or "output end" of the trough 1604 is reached, the food product 115 will be appropriately sterilized and will exit through an opening 1668 in the bottom of trough thereby entering the chute 1670 and is then deposited on the discharge device 1628.

Fig. 16 shows an inclined embodiment of screw conveyor sterilizer 1600, wherein the food product 115 is transported from the lower (receiving) end 1672 of the screw conveyor sterilizer to its upper (discharging) end 1676. However, embodiments of the sterilizer 1600 may be horizontal or reversely inclined (i.e., the receiving end 1672 is

higher than the discharging end 1676) as well. The end bells 1652 and 1656 carry the bearings 1660 and the end bells are fixed (bolted or welded) to the trough 1604 so that the auger assembly 1608 can rotate within the trough without hitting or rubbing the walls of the trough.

In Fig. 16, food product 115 enters the screw conveyor sterilizer 1600 from an infeed device 1624 which includes a conveyor 116 and food product storage hopper 1680 (this hopper also functioning to prevent the food product 115 from spilling out of the receiving end 1672 of the screw conveyor sterilizer 1600). In at least one embodiment, the product infeed device 1624 may be a material handling apparatus, such as a shaker conveyor, belt conveyor, auger conveyor, etc. which provides an even flow of foodstuff 115 to the screw conveyor sterilizer 1600. The discharge device 1628 may be attached to an auger support structure 1684. Moreover, the discharge device 1628 may be a conventional food product conveyor as one skilled in the art will understand.

Since the ends of the screw conveyor sterilizer 1600 may be partially open (e.g., openings 1664 and 1668), there is the possibility of UVC light escaping from the interior of the screw conveyor sterilizer. Accordingly, at least in areas where an operator and/or other personnel may be subject to such radiation, the UVC is substantially prevented from exiting the volume enclosed by the screw conveyor sterilizer 1600. In particular, the lid/reflector subassembly 1636 may have a shape and be fabricated from a material that effectively prevents harmful radiation from exiting through it and at the seam or contact points with trough 1604. Additionally, the UVC light may be attenuated or completely blocked from exiting the volume of the screw conveyor sterilizer 1600 by radiation attenuating baffles (not shown) on the infeed (i.e. receiving) end 1672 of the screw conveyor sterilizer, and also on the discharge end 1676. Note that such baffles may be substantially similar to any one of the embodiments of UVC attenuating baffles 1191 described hereinabove.

Figs. 15A-15D show various alternative cross sectional end view embodiments of the screw conveyor sterilizer 1600 showing various lifting tumbler 1620 configurations.. The tumblers 1620 between the flights 1616 of the auger assembly 1608 lift and tumble the foodstuff 115 in the presence of the UVC light indicated by the arrows directed outwardly from, e.g., the reflector/lid assembly 1636 and from the UVC emitters 161.

Note that in some embodiments, there is a reflector 1688 that is substantially distinct from the trough lid 1692 (which also functions as a UVC attenuating baffle.

The retention time of the food product 115 in the screw conveyor sterilizer 1600 is substantially determined by the following values: the auger assembly 1608 rotational speed, the auger pitch (i.e., the auger pitch is the distance between the flights 1616, which defines the length of food product 115 movement with each revolution of the auger shaft 1612), and the auger assembly length. Accordingly this retention time substantially determines the time that any particular food product item may be exposed to the UVC light. It is believed that for most food products 115 and operational configurations of the screw conveyor sterilizer 1600 that a UVC exposure time for each item of the food product should be within the range of from 2 seconds to 60 seconds. Moreover, the following values determine the amount of UVC energy (in microwatts-second per centimeter squared) that may be utilized for sterilizing the food product 115 passing through the screw conveyor sterilizer 1600: the amount of UVC energy emitted by the UVC emitters 161 (adjusted for the emitter ambient operating temperature and distance from the emitters to the food product), the retention time of the food product in the screw conveyor sterilizer 1600, and the surface area of the food product 115 exposed to the UVC light.

In one preferred embodiment, the UVC emitters 161 are attached in a fixed position to a frame portion (not shown) of the lid/reflector subassembly 1636 with one or more quick disconnect pin connectors 1696 (Fig. 6 or Fig. 11) for performing maintenance on the UVC emitters, e.g., removal and cleaning, or replacement. The screw conveyor sterilizer 1600 may include UVC attenuating baffles surrounding any portions of the sterilizer 1600 where UVC light may likely escape into the environment surrounding the sterilizer. Note that either of the electrical coupling embodiments 169 and 169A may be also used with the sterilizer 1600. In particular, these electrical couplings allow the emitters 161 to be easily removed and manually cleaned during sanitizing activities in a food processing plant, while providing a watertight electrical connection if cleaned in place, or during operation of the emitters 161.

The power supplies and ballasts providing electrical power to the UVC emitters 161 of the sterilizer 1600 may be substantially identical to those used with the drum

embodiment of the surface sterilizer. In one embodiment, such power supplies and ballasts are either remotely mounted in a water tight, corrosion resistant electrical enclosure, referred to in the industry as a NEMA 4X electrical enclosure, or enclosed in a watertight assembly as shown in Fig. 5 of the light assembly 145. Such a light assembly 145 may be constructed for the sterilizer 1600 that is watertight and may have the emitters 161 arranged in flat (i.e., planar), convex or concave configurations. For the UVC emitters 161 to operate effectively in environments where the ambient temperature will vary from -40 (i.e., negative forty degrees) degrees Fahrenheit to 120 degrees Fahrenheit, it is preferred that the emitters 161 be UVC low pressure mercury single ended emitters such as those manufactured by Steril-Aire, Inc., 11100 E Artesia Boulevard, Unit D, Cerritos, CA 90703 wherein the UVC emitters are supplied separately from the power supplies and ballasts so that the emitters and these other electrical components need not be located immediately adjacent to one another. Additionally, the UVC emitters 161 may be enclosed in a plastic material (not shown), which is applied in a shrink wrap fashion to each emitter so that the plastic material fits tightly to the emitter. Moreover, as described previously, the plastic material does not substantially reduce or alter the UVC light generated by the emitters, and is of appropriate strength to contain the glass particles in the event such an emitter is shattered. Steril-Aire Inc. single ended emitters are commercially offered by Steril-Aire Inc. with or without such a plastic coating. The Sterile-Aire Inc. single ended emitters are typically available in lengths of 16 inches, 20 inches, 24 inches, 30 inches, 36 inches, and 42 inches. The length(s) of the UVC emitters 161 used in an embodiment of the screw conveyor sterilizer 1600 may be selected to be compatible with the length of the sterilizer 1600 and, e.g., the design of the lid/reflector subassembly 1636. Moreover, note that the Steril-Aire UVC Emitter provides from 50 watts to 70 watts of UVC radiation per emitter. UVC germicidal emitters 161 are also manufactured commercially by other companies, such as Aquionics, Inc. 21 Kenton Lands Road, Erlanger, KY 41018, and American Ultraviolet 2400 W. Cape Cod Way, Santa Ana, CA 92703.

In a similar manner to the rotating drum embodiment of the invention, the emitters 161 (and their corresponding reflectors 1688 or lid reflective surfaces 1640) used in an embodiment of the sterilizer 1600 direct the radiated UVC light in the direction of

the food product 115 in the screw conveyor sterilizer 1600. The UVC reflector 1688 or reflective surfaces 1640 may be manufactured of a reflective and corrosive resistant material such as previously identified above for UVC reflector materials. In one embodiment, the shape of the UVC light reflector 1688 or the reflective surfaces 1640 is such it directs the UVC light to the area where the food product 115 is being tumbled as shown in Figs 15a through 15d. Note that the UVC light support (not shown) is typically in a fixed location and position so that the stationary UVC emitters 161 and UVC reflector 1688 (or reflective surfaces 1640) remain in a constant position relative to the food product 115 being lifted and tumbled within the auger assembly 1608 by the tumblers 191.

The screw conveyor sterilizer support frame 1684 (e.g., Fig. 16) includes structural support assemblies manufactured of corrosion resistant materials such as stainless steel angles or tubes, and engineered for adequate structural strength to support the imposed loads with a minimum of deflection. The frame 1684 may be manufactured with continuous welds to prevent the creation of crevices in which food particulates and bacteria could harbor, and to allow the frame to be easily sanitized. The support frame 1684 typically is in a stationary position relative to the auger trough 1604 and the rotating auger assembly 1608. Thus, the support structure 1684 typically holds the auger trough 1604 in a stationary position relative to the rotation of the auger assembly 1604.

Many food products 115 are weighed prior to packaging on multiple select scales, which are common in the food processing industry, and which are often arranged in a circular configuration with the food product 115 entering at a center area of the circular configuration. For food processing applications with such a circular arrangement of such multiple select scales, the screw conveyor sterilizer 1600 may be ceiling mounted so that the discharge device 1628 of the sterilizer 1600 can be located so that the food product is deposited downwardly into the center of the circular scale area.

Since each of the UVC light reflectors 1688 (or the or reflective surfaces 1640) may be designed for positioning at a fixed distance and orientation to both the associated emitters 161, and the in-trough food product 115, the distance of the UVC emitters to the food product is limited by the diameter of the auger assembly 1608. That is, during rotation of the auger assembly 1608, the auger flights 1616 are, e.g. , within less than

0.125 inch clearance of the bottom of the trough 1604. Thus, the outside diameter of the auger flights 1616 define the closest the emitters 161 can be to the centerline of the auger shaft 1612, and therefore, to the foodstuff 115 in the bottom of the auger trough 1604, and to the foodstuff being lifted and tumbled by the tumblers 1620.

The trough 1604 and auger assembly 1608 are manufactured of non-corrosive material such as stainless steel, aluminum or a plastic. The inside surface of the trough 1604 and the surfaces of auger assembly 1608 are preferably polished to increase the reflectivity of the UVC light within the screw conveyor sterilizer 1600. Alternatively, the trough 1604 may have a liner with an inside surface of polished stainless steel, polished aluminum, polished zinc, or polished coatings such as magnesium carbonate, nickel or chromium. Moreover, the various surfaces of the auger assembly 1608 may have a similar polished coating. Also, the trough 1604, auger shaft 1612, and auger flights 1616 have material thicknesses selected to provide adequate structural strength for the imposed foodstuff 115 loads that are transported through the trough. The trough 1604 and auger assembly 1608 may be manufactured with continuous welds both to prevent the creation of crevices in which food particulates and bacteria could harbor, and to allow the screw conveyor sterilizer 1600 to be easily sanitized.

In one embodiment of the sterilizer 1600 for food products 115 which are sensitive to temperature change, the trough 1604 is insulated with an insulation material such as polyurethane, polystyrene, fiberglass, or calcium silicate. The insulation material may be sheeted with stainless steel on the exterior to enclose the insulation. The insulation is selected to minimize conductive heat transfer to the exterior of the trough 1604. As an aside, note that the drum 111 of the rotating drum embodiments of the sterilizer 181 may also be similarly insulated.

In food processing applications with frozen products in unconditioned ambient environments, the trough 1604 may also be insulated to prevent the sweating of the exterior of the trough 1604 caused by condensation of moisture from the unconditioned ambient environment. Also, the trough 1604 could be jacketed and heated with resistance type electrical wire or jacketed for cooling or heating with cold thermal fluid, hot thermal fluid, or steam. In another embodiment, the trough 1604 may be manufactured of sheet metal material with perforations or holes, which serve to separate

solid materials and liquid materials, and/or to allow materials of a lesser particle size than desired to be separated from the flow of foodstuff 115 through the screw conveyor sterilizer 1600. Examples of food processing applications wherein a perforated trough 1604 is desirable are: the processing of raw whole potatoes where surface dirt is removed and the dirt is allowed to pass through the perforations in the trough, and/or the processing of vegetable products that are conveyed by the pumping of water and wherein the vegetables are to be separated from the water by allowing the water to pass through the perforations in the trough.

In the screw conveyor sterilizer 1600 embodiment of Fig. 16, the sterilizer is inclined relative to the hopper 1680 and receives a consistent flow of food product 115 from a bulk supply in the hopper for irradiation by UVC light. UVC attenuating baffles (not shown) may be provided adjacent to or surrounding the: (a) the inlet or infeed device 1624, and/or (b) the discharge device 1628 for thereby: containing the ultraviolet light within the screw conveyor sterilizer 1600 as a safety feature to protect the eyes and the skin of personnel in the area near the sterilizer, and/or altering such UVC light which escapes from the sterilizer 1600 so as to not cause health damage to employee eyes or skin. Additionally, the screw conveyor lid/reflector subassembly 1636 is manufactured using UVC attenuating materials. Such UVC attenuating materials include opaque metal or plastics such as are typically used as welding curtains for similar protection of eyes and skin of personnel in the area of the welding activity. In some embodiments of the sterilizer 1600 that include a perforated trough 1604, the UVC attenuating materials may be required around the entire screw conveyor sterilizer 1600 for the protection of eyes and skin of personnel in the area of the ultraviolet rays.

The rotational motion of the auger assembly 1608 is caused by a drive motor (not shown). There may be one or more power transmission components (also not shown) for transferring the rotation motion to the auger assembly 1608 from the drive motor. The auger shaft 1612 is supported in bearings on the auger end bells 1648 which may be supported by the support frame 1684 as described above. The power transmission components cause motion from the drive motor to be transmitted to the auger shaft 1612 at an intended rotational speed. It is well known to those in the food processing arts that there are various methods to cause the rotational motion of the auger assembly 1608,

such as timing belts, roller chain and sprocket drives, v belts, etc. These components are readily available from manufactures such as Baldor Motors and Drives, 5711 R. S. Boreham Jr. St., Fort Smith, AR 72908, Martin Sprocket and Gear Inc., 3100 Sprocket Dr., Arlington, TX 76015-2828, etc. The rotational speed of the auger assembly 1608 may be adjustable for altering the retention time of the foodstuff 115 in the sterilizer 1600 being exposed to the UVC light. Rotational speed adjustment with AC electrical three phase motors can be accomplished with variable frequency electronic drives, which are common to those familiar with the arts. Variable frequency drives are readily available from manufacturers such as Allen Bradley Co. Inc., 1201 South Second St., Milwaukee, WI 53204. The auger assembly 1608 may also be rotated at varying speeds with hydraulic motors in combination with fluid flow adjustment valves, which are common to those familiar with the arts. The auger assembly 1608 may have a rotational speed range of from less than one revolution per minute to about sixty revolutions per minute.

In operation the foodstuff 115 is deposited into the sterilizer 1600 by the product infeed device 1624, thereby providing an accumulation of foodstuff in the bottom of the trough 1604. The foodstuff depth in the bottom of the trough 1604 is usually below the bottom surface of the auger shaft 1612. In operation, the tumblers 1620 are continuously moving with the rotation of the auger assembly 1608. Each of the lifting tumblers 1620 protrudes from a surface 1698 (Fig. 14) of one of the auger flights 1616 at an angle of, e.g., approximately 90 degrees to this auger surface. However, other angles in the range of 15 to 90 degrees are also possible. In some embodiments, each of the lifting tumblers 1620 is substantially planer and parallel to the rotational axis of the auger assembly 1608. Each of the lifting tumblers 1620 may be fixedly attached to at least one the flights 1616 such that the lifting tumbler extends inwardly from an outermost flight edge 1700 (Figs. 14 and 15) of the auger assembly 1608 towards the shaft 1612. In one embodiment, the lifting tumblers 1620 may be short (in the direction generally towards the shaft 1612), and accordingly they may not extent the full distance to the shaft 1612, and thus such a lifting tumbler does not continuously span the extent from the shaft to the outside edges 1700 of the auger flights furthest from the shaft. Assuming that each of the lifting tumblers 1620: (a) extends from the outer edge 1700 of the flights 1616 toward the shaft 1612 by at least an amount corresponding to an expected depth of the foodstuff 115 in the

bottom of the trough 1604, and (b) spans substantially the entire distance between the two consecutive flights 1616 that the lifting tumbler is positioned, then upon rotation about the shaft 1612, each of the lifting tumblers 1620 can lift substantially all the foodstuff in the bottom of the trough 1604 between the flights which the lifting tumbler is positioned on each shaft 1612 revolution. In some embodiments of the sterilizer 1600 such lifting tumblers 1620 can extend from the shaft 1612 to the outmost edges 1700 of the flights 1616. Alternatively, there may be lifting tumblers 1620 that extend towards the shaft 1612 from the outermost edges 1700 of the auger flights 1616 only part of the expected foodstuff 115 depth, in which case such lifting tumblers may lift only an expected predetermined portion of the foodstuff in the bottom of the trough 1604 between the flights that such a lifting tumbler is positioned with each revolution of the shaft 1612.

For a specific food surface sterilization application wherein the sterilizer 1600 is used, the following values must be known: (i) the range in foodstuff flow rate (in weight per time increments), (ii) the range in foodstuff 115 bulk density (in weight per unit of volume), and (iii) the desired destruction rate for the most resistant anticipated bacteria, yeast, fungi, and/or mold spores. The application combines the effects of the auger assembly 1608 diameter, auger pitch, emitter 161 and reflector surface 1640 assembly length, auger assembly rotational speed, and the quantity, location, operating temperature, and wattage of the UVC emitters 161 to provide the required UVC dosage to substantially all foodstuff surfaces to achieve the desired destruction rate of the most resistant anticipated bacteria, yeast, fungi and/or mold spores.

Additionally, it is important to note that embodiments of the screw conveyor sterilizer 1600 can be controlled using a controller that is substantially similar to the controller 1400 described hereinabove for rotating drum embodiments of the present invention. It is believed that given the above description of the controller 1400, one of ordinary skill in the art can also make and use a controller for various sterilizer 1600 embodiments. In particular, such a controller for controlling one or more sterilizers 1600, may be a simpler version of the controller 1400 in that there may be no corresponding functionality for changing an inclination of a sterilizer 160, and there may be no corresponding functionality needed for sensing and determining whether there is a food product blockage within the trough 1604. Thus, a controller for one or more sterilizers

1600 may be no components corresponding to: the drum inclination controller 1460, the drum inclination sensor 1469, the drum inclining device 1468, and in-drum food product load blockage sensor(s) 1424. However, substantially all other components of the controller 1400 may be translated into corresponding components for a sterilizer 1600 controller by replacing the term "drum" with "trough and/or auger assembly", replacing the term "in-drum" with "in-trough", and changing any numerical labeling to be consistent with the labeling of sterilizer 1600 components of Figs. 14-16.

Moreover, it is also an aspect of the invention, that since controllers for various embodiments of the invention are so similar, that a single controller may be used to control different embodiments of the surface sterilizer 181. Thus, such a controller may control both one or more rotating drum embodiments, and additionally control one or more screw conveyor sterilizer 1600 embodiments.

The following example illustrates a method for configuring and using the screw conveyor sterilizer 1600.

Example 3 Frozen Whole Kernel Corn in a Rotary Screw Conveyor

Frozen, whole kernel corn is to be surface sterilized prior to being provided to a multiple select scale unit, which is circular from a plan or overhead view. Since the food product is to be introduced to the center of the scale unit, the embodiment of the sterilizer 181 is an screw conveyor sterilizer 1600 which is supported to provide for suspending at least the discharge device of the screw conveyor above the multiple select scale. Assuming the whole kernel corn is frozen, and is being sterilized in an unconditioned ambient atmosphere; the trough 1604 may be insulated to prevent condensation on the exterior of the trough, wherein the condensation could drip onto the whole kernel corn on the multiple select scale. The flow rate of the whole kernel corn through the screw conveyor sterilizer 1600 is limited by the scale to no more than 100 weighments per minute of 1 pound per weighment, or a flow rate of 100 pounds of whole kernel corn per minute. Bulk density of the whole kernel corn is 46 pounds per cubic foot; therefore, volume flow rate is 2.17 cubic feet per minute (100 lb/minute * 1 ft^3/46 lb).

The screw conveyor sterilizer 1600 is configured to kill 99% of Listeria monocytogenes bacteria at a dosage of 19,000 microwatts-seconds/centimeter squared.

At this UVC dosage, the exposure time is expected to be 6 seconds for each surface of the tumbling whole kernel corn. UVC irradiance sterilization efficiency is reduced to 33% to assure that all surfaces of the whole kernel corn are adequately exposed to the UVC germicidal radiation. Therefore, the exposure cycle time for the flow of whole kernel corn through the screw conveyor sterilizer 1600 may be no less than 18 seconds (6 second exposure * 1/0.33 efficiency). At a volume flow rate of 2.17 cubic feet per minute, and a 18-second exposure cycle time, the volume of whole kernel corn per exposure cycle is no more than 0.65 cubic feet (2.17 ft^3/minute * 18 seconds/exposure cycle * 1 minute/60 seconds). An auger assembly 1608 having an auger flight 1616 diameter of 8 inches, and an UVC emitter 161 lid 1636 length of 8 foot is selected, wherein there are tumblers 1620 between the flights 1616 in the length of the lid 1636 with UVC emitters 161. A food product average depth of no more than 3 inches is preferred to provide clearance with the center shaft 1660 of the auger assembly 1608. Thus, when the whole kernel corn is being tumbled within the auger assembly 1608, it is being lifted by the tumbler 1620 on each revolution of the auger flights 1616. At a product depth of 3 inches in the auger trough, 68% of the lower half of the trough 1604 is occupied by whole kernel corn. With the lid 1636, including UVC emitters 161, being 8 feet long, the maximum quantity of whole kernel corn in each cycle is equal to 0.95 cubic feet (3.14 * 4 inches * 4 inches * ½ * 0.68 * 1 ft^2/144 in^2 * 8 ft). Since 0.95 cubic feet is greater than the volume of whole kernel corn per exposure cycle (i.e. 0.65 cubic feet/exposure cycle), it is believed that the screw conveyor configuration will be adequate for the expected flow rate of whole kernel corn. The exposure area of the whole kernel corn in the screw conveyor sterilizer 1600 is based on the trough 1604 width, the lid 1636 (with the UVC emitters 161) length, multiplied by six times to account for the quantity of sides on the cube shaped whole kernel corn pieces, at least one of these sides exposed to UVC light at any time. The exposure area of the whole kernel corn is 32 square feet (8 inch * 1 ft/12 inch * 8 ft * 6 times). Assume that a quantity of (8) UVC emitters 161 are selected which are 24 inches long each, wherein these emitters are mounted within the screw conveyor lid 1636 so that they are arranged to be offset from the exposed whole kernel corn by an average of 4 inches. Further, assume that the UVC energy level of each emitter 161 is 50 watts, and that this energy level is de-rated to 80% energy for the

refrigerated ambient temperature inside the screw conveyor sterilizer 1600 caused by the flow of the frozen whole kernel corn, and additionally de-rated to 58% due to the distance from the emitter to the exposed whole kernel corn. Therefore, effective energy contacting the whole kernel corn after the cumulative adjustments for temperature and distance is 23.2 watts/emitter (50 watts/emitter * 0.8 temperature derate * 0.58 distance derate), or total 185.6 watts from the 8 emitters. Thus, UVC energy for irradiating the whole kernel corn is approximately 37,460 microwatts-seconds/cm^2 (185.6 watts * 6 seconds * 1/32 ft^2 * 1 ft^2/929 cm^2 * 1,000,000 uw/w) resulting in a safety factor of 2.0 for the target 99% kill rate of Listeria monocytogenes. Inclination angle and drum rotational speed are adjusted so that the whole kernel corn indeed flows through the screw conveyor with a 24 second exposure cycle time. Accordingly, with the application of the surface sterilization process provided by the screw conveyor sterilizer 1600 immediately before the packaging of the whole kernel corn, any bacteria that contaminated the surface of the whole kernel corn will be killed or inactivated at a 99% destruction rate. Therefore, the potential for whole kernel corn waste, recall from market, bio-terrorism and consumer illness from consumption of contaminated whole kernel corn is greatly reduced. In recent years, improvement in the testing and detection of bacteria in foodstuffs have provided for the detection of much smaller concentrations of bacteria; therefore, due to increasingly smaller amounts of detected bacteria, there has been increased cost to the food processing industry associated with product waste, recalls, and consumer claims. The present invention as demonstrated in this example substantially solves surface contamination of food products.

The foregoing discussion of the invention has been presented for purposes of illustration and description. Further, the description is not intended to limit the invention to the form disclosed herein. Consequently, variation and modification commiserate with the above teachings, within the skill and knowledge of the relevant art, are within the scope of the present invention. The embodiment described hereinabove is further intended to explain the best mode presently known of practicing the invention and to enable others skilled in the art to utilize the invention as such, or in other embodiments, and with the various modifications required by their particular application or uses of the invention.